Exhibit A

SAMPLING & ANALYSIS PLAN
FOR THE
COLUMBIA RIVER CHANNEL DEEPENING

MAY 14, 1997

Prepared by:

Portland District
Corps of Engineers

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PROJECT DESCRIPTION, SITE HISTORY AND ASSESSMENT

1.1 Project Description. The Columbia River rises in British Columbia, through which it flows for 425 miles. It enters the United States in northeastern Washington, and empties into the Pacific Ocean 645 miles north of San Francisco Bay and 160 miles south of the Strait of Juan Defuca. Total length of river is 1,210 miles and forms a boundary between the states of Washington and Oregon. The Willamette River rises in the Cascades Range in western Oregon, flows northerly, and empties into the Columbia River at Portland, Oregon about 100 miles from the sea. Its length from source of the Middle Fork is about 294 miles. Dredging is primarily concentrated in those reaches from the mouth to about RM 103.5 on the Columbia and to RM 11.1 on the Willamette along with several side channels, marinas, and docking facilities (see Appendix A for historic perspective and shoal descriptions). This sediment evaluation study only covers those sediments associated with the proposed deepening of the Federal channel to 43 feet. Sediment quality in the berthing areas or non-federal access channels of the seven deep-draft ports on the lower Columbia River that rely on the channel, including Astoria, St. Helens and Portland in Oregon, and Longview, Kalama, Woodland and Vancouver in Washington as well as all side channels will not be a part of the study area or this evaluation.

During this study sediment will be collected and subjected only to physical and chemical analyses depending on location and sediment characteristics. No biological analyses are to be conducted at this time. Depending upon the results of the feasibility study and final project design, it is expected that additional testing and evaluation will be necessary particularly along the Willamette River prior to dredging. No dredging relevant to Columbia River Channel Deepening is scheduled prior to 2003 after completion of the study and congressional authorization.

1.2 Site History. The navigation channel from the mouth of the Columbia River to Portland, Oregon was first approved in 1877. In 1882 a 30-foot entrance channel was approved. It wasn't until 1894 that the first extensive channel dredging occurred. In 1905 a 40-foot entrance channel was initiated at the mouth of the Columbia River. By 1917 the north jetty was completed and the channel stabilized below 40-foot. Fourteen million cubic yards were removed in 1956 during constructing of a 48-foot entrance channel. In 1977, 9 million cubic yards of material was removed during the construction of an authorized 52-foot entrance. The entrance channel was deepened to its present authorized depth of 55 feet between 1984 and 1986. Since 1956, approximately 160 million cubic yards of sand have been dredged from the entrance channel with an annual average of 4.1 million cubic yards. All material is removed by hopper dredge and placed at ocean disposal sites.

In 1899 the navigation channel to Portland was authorized to 25-foot (see Figure 1). This was increased to 30-foot in 1912. Construction beginning in 1914 with extensive dredging and pile dike construction. There was also extensive filling of the water front in Astoria, Oregon. The Columbia River channel was authorized to 35-foot in 1930 with construction completed in 1935. This provided the present channel configuration and established the pile dike system. The present 40-foot channel was authorized in 1962 with construction completed in 1976 (see Appendix B).

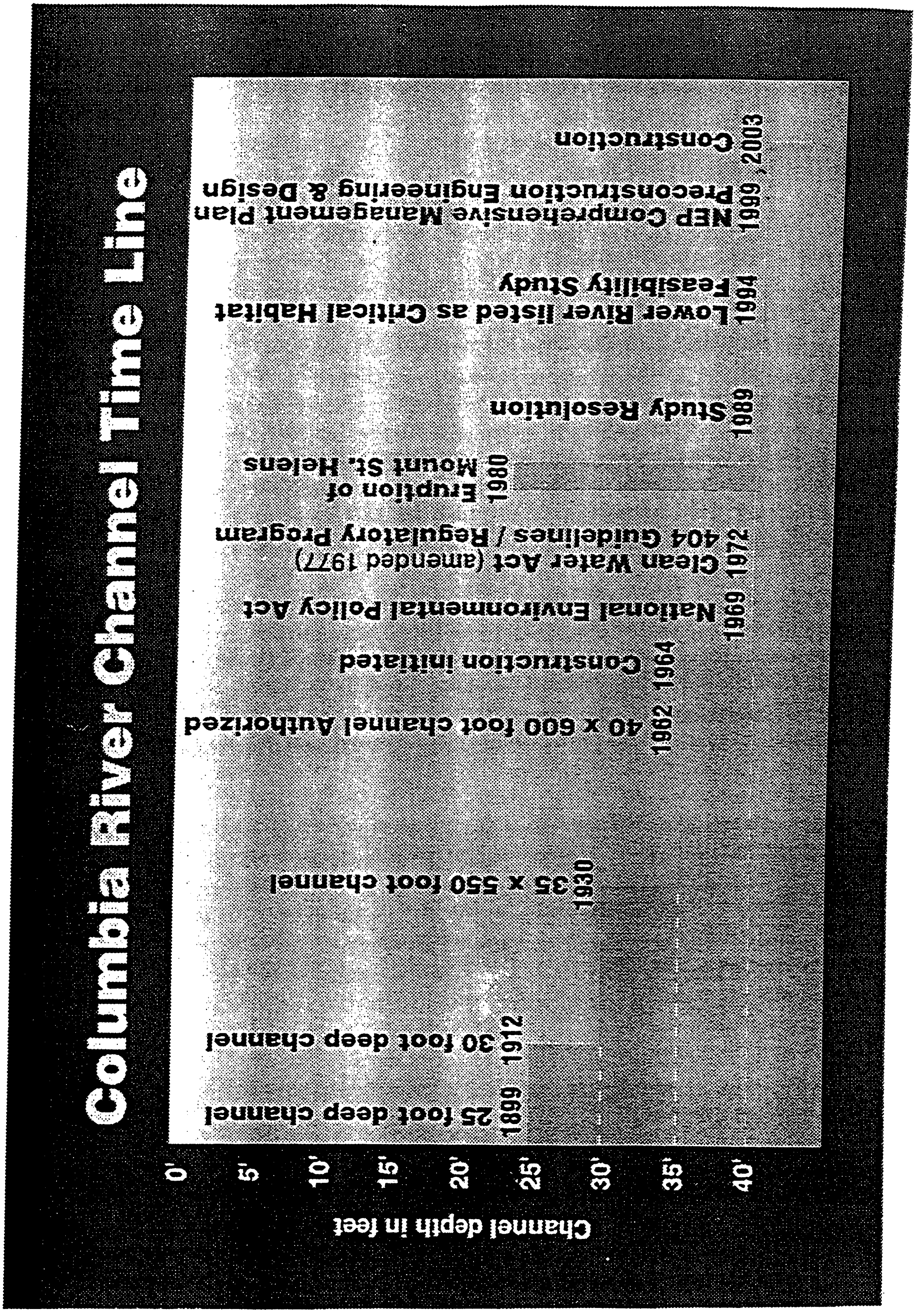


Figure 1: Columbia River Channel Time Line.

1.3 Shoaling. The vast majority of the Colombia River navigation channel shoaling is from the direct result of bedload transport. The two dominate shoal forms in the Columbia River are large sand waves and cutline shoals (see Appendix C). Sand wave shoals are present throughout the river channel and cause shoals across the channel. The main source of material for sand waves is the bed of the navigation channel. Dredging leaves a flat channel bottom on which the waves form. The wave troughs are scoured from below the dredged surface, with material from the trough then forming a wave crest. Sand wave shoals do not appear at the same location each year because of the time required for the waves to form and grow.

Cutline shoals are much larger and run parallel to the channel and develop at the same location year after year. They form along the navigation channel dredging cutline, parallel to flow, and can extend several thousand feet along the channel. Cutline shoals begin forming at the edge of the dredged cut and grow out towards the center of the navigation channel. The primary cause of the cutline shoal is gravity pulling bedload material down the side-slops and into the navigation channel.

1.4 Previous Sediment Sampling. The proposed Columbia River Channel Deepening Project consists of two distinct and different regimes with respect to sediment physical and chemical properties. The two are the lower 11.6 miles of the Willamette River and the mainstem Columbia River (see Appendix B). In the Willamette River a cutline shoal develops between RM 8.0 and 10.1 along the west side of the channel. This has been the primary location requiring maintenance dredging every 2 to 5 years. Other areas are dredged less frequently. Willamette River sediments have been subjected to chemical characterization because of the characteristics of the material dredged and close vicinity of numerous know sources of contamination (see Appendix D). While the bulk of the material evaluated from the present 40-foot channel has been found to be suitable for unconfined aquatic disposal, some material has been found to be unsuitable. The majority of the material to be dredged from the proposed channel deepening project has not been evaluated. Columbia River mainstem sediments are comprised of sand with less than 2-5% in the silt to clay size classification.

2.0 SAMPLING AND ANALYSIS OBJECTIVES

The sediment characterization program objectives and constraints are summarized below:

- To characterize sediments to confirm or establish area rankings in accordance with the draft Regional Dredge Material Testing Manual (RDMTM).

- To provide information needed to develop a baseline cost estimate relative to proper disposal of dredged material.

- To provide information for the CRCD EIS sufficient to describe the material to be potentially dredged.

- Only physical and chemical characterization will be conducted. It is anticipated that additional chemical and biological testing shall be required prior to dredging commensurate with the proposed disposal method and RDMTM.

3.0 SAMPLING AND ANALYSIS REQUIREMENTS

3.1 Project Ranking. Present project rankings are shown in Table 1. These initial rankings were a product of the team developing the RDMTM and were based upon existing information or lack of information (see Table 2 for rank descriptions). Higher ranks are assigned to areas known to be contaminated or which lack information and can only be downranked pending additional information. Information gathered by this study will be used to verify or modify existing ranking. Areas, particularly in the Willamette River, will be sampled which have not been previously sampled. Project ranking through this study can only be verified or increased in rank, no down ranking is possible as two sampling and analyses events are required to down rank an area.

Table 1: Project Area Rankings

PROJECT AREA	PROJECT	RANK				
		EXCLUSIONARY	LOW	LOW - MODERATE	MODERATE	HIGH
Main Stem Columbia	RM 5 to 20	X				
	RM 20 to 29	X				
	RM 29 to 47	X				
	RM 47 to74	X				
	RM 74 to 88		X			
	RM 88 to 99	X				
	RM 99 to 106		X			
Willamette River						
	RM 0 to 3		X			
	RM 3 to 10			X		
	RM 10 to 11.1				X	
	RM 8 to 10 O&M Shoal		X			

3.2 Sampling and Analysis Requirements.

Mainstem Columbia River:

The material proposed to be dredged from the mainstem of the Columbia River consist of clean sands low in fines and organic content. The areas identified consist of sand wave or cut line shoals formed by bedload transport. Material distribution in these shoals are homogeneous due to source and consistency of the hydraulic regime which form the shoals. Samples, therefore, will be collected by a modified 0.96m Gray O'Hare box corer. Based upon past sampling by the Corps and information gathered through Bi-State studies several areas have been ranked exclusionary or low. All shoals identified as requiring removal under the channel deepening project (a total of 67) will be sampled and physically analyzed for grain size and volatile solids. Some sideslope areas will also be sampled. Selected areas will also be subjected to chemical analyses. These areas have been identified by past Corps testing, the Bi-State study, or proximity to known sources as having the potential to be contaminated. It is anticipated that a total of 100 physical analyses will be conducted. Ten persecute of these will be subjected to chemical analyses.

Table 2: Ranking Guidelines

RANK	GUIDELINES	EXAMPLES
Exclusionary	Coarse grain material (greater than 80% retained on a No. 230 sieve); TVS< 5%; sufficiently removed from sources (based on historical information or BPJ).	MCR, Main Col. R. Chinook Ch.
Low	Few or no sources of chemicals of concern, data are available to verify low chemical concentrations (typically below a level predicted to result in significant biological effects) or no significant response in biological tests.	Elochoman Slough
Low-Moderate	Available data indicate a "low" rank, but there are insufficient data to confirm the ranking.	CRCD-Willamette R.
Moderate	Available data indicate chemical concentrations within a range associated historically with potential for causing adverse biological impacts. **or** Sources exist in the vicinity of the project, or there are present or historical uses of the project site, with the potential for producing chemical concentrations within a range associated historically with some potential for causing adverse biological impacts.	
High	Known chemical sources, high concentrations of chemicals of concern, or significant responses in at least one of the last two cycles of biological tests. (When a "high" rank is indicated for an area based on preliminary data, then a "high" rank is assigned to the area as a protective measure. That is, there is no rank of "high-moderate").	U.S. Moorings McCormick & Baxter

Willamette River:

Material in the Willamette River varies from medium to fine sands at the mouth to over 80% fines (silts and clays) further up the channel. Contamination of sediments in the study area range from uncontaminated to highly contaminated. There are numerous sources of contaminates ranging from combined sewer/storm water outfalls to identified superfund sites and industrial sites. In the lower sections of the river shoal areas to be removed are scattered along the sides of the proposed new cut. The depth varies from 0.0 to 3.0 feet. Above RM 7.5 shoals are typically 5.0 to 6.0 feet (the difference between the existing and proposed 43-foot channel). There are several areas however where deeper areas will have to be removed. The deepest cut will be in the proposed turning basin at RM 11.4 between the Fremont and Broadway bridge. Here on the left (west) side of the channel up to 24 feet of material will have to be removed.

Because of the variation in the depths of material that is projected to be removed different sampling equipment will have to be used. For areas where 0.0 to 3.0 feet of material will have to be removed a modified 0.96m Gray O'Hare box corer will be used. In areas with material 3.0 to 6.0 feet thick, a 3.5" Benthos gravity corer will be used. In areas greater than 6.0 feet a coring device capable of sampling the entire cut will be used. This may be a vibracorer, impact corer, or split spoon coring device depending on the equipment provided by the contractor. These longer cores will be subdivided into 6.0 foot sections for separate analyses. All samples will be subjected to physical and chemical analyses.

4.0 SAMPLE COLLECTION AND HANDLING PROCEDURES

4.1 Sampling Locations and Numbering. Figures in Appendix B show the project and sample locations. Proper QA/QC procedures as outlined in this section will be followed. Any deviation from these procedures shall be noted in the field log. Sample identification shall follow the following convention:

CR-XX-YY(Z) or WR-XX-YY(Z)

Where CR and WR denote samples collected from the Columbia River and Willamette River respectively. "XX" denotes the type of sampling device such as BC-box corer, GC-gravity corer, P-ponar; "YY" denotes the numeric sample number and will consist of two digits for all samples (i.e. 01, 09, 44, 69 etc.). For cores an alpha character (i.e. A, B, C, etc.) will to denote vertical location as represented here by "Z". The core will be divided in 6-foot sections starting from the surface until the project depth is reached or end of core. The top section will be labeled WR-XX-YYA, the next section WR-XX-YYB, and so forth to project depth. Any material retrieved from below the project depth will be sampled and labeled with the alpha character "Z". These "Z" labeled samples will be delivered to the NPD Materials Testing Laboratory with the rest of the samples for processing. The chain-of-custody form will indicate that these samples are to be held pending decisions as to possible chemical analyses.

4.2 Field Sampling Schedule. Sampling is planned for June and July 1997.

4.3 Field Notes. Field notes will be maintained during sampling and compositing operations. Included in the field notes will be the following:

- Names of the person(s) collecting and logging in the samples.
- Weather conditions.
- Depth of each station sampled as measured from the water surface. This will be accomplished using a leadline or corrected depth recorder.
- Date and time of collection of each sediment sample.
- The sample station number and individual designation numbers assigned for each individual sample.
- Descriptions of sediment or core sections.
- For cores, the length of core and the penetration depth of the sampling device.
- Any deviation from the approved sampling plan.

4.4 Positioning. Sampling locations will be recorded. Horizontal coordinates will be referenced to the Washington Coordinate System for proper North or South Zones NAD 27 (North American Datum 1927). Horizontal coordinates will be identified as latitude and longitude to the nearest 0.1 second.

4.5 Decontamination. All sampling devices and utensils will be thoroughly cleaned prior to use according to the following procedure:

- Wash with brush and Alconox soap
- Rinse with distilled water
- Rinse with 10% nitric acid solution
- Rinse with distilled water

Utensils used to collect physical samples only or sampling devices such as the box corer will be washed down before each sampling event. However, they will not require the cleaning procedure listed above as long as samples collected for chemical analyses are not in contact with the core walls. All utensils used to collect chemical samples will require decontamination prior to each use. All hand work for chemical analyses will be conducted with disposable latex gloves which will be rinsed with distilled water before and after handling each individual sample, as appropriate, to prevent sample contamination. Gloves will be disposed of between samples or composites to prevent cross contamination between samples.

4.6 Core Logging. Each discrete core section will be inspected and described. For each core sample, the following data will be recorded on the core log:

- Depth interval of each core section as measured from MLLW.
- Sample recovery
- Physical soil description in accordance with the Unified Soil Classification System (includes soil type, density/consistency of soil, color)
- Odor (e.g., hydrogen sulfide, petroleum products)
- Visual stratification and lenses
- Vegetation
- Debris

- Biological Activity (e.g., detritus, shells, tubes, bioturbation, live or dead organisms)
- Presence of oil sheen
- Any other distinguishing characteristics or features

4.7 Field Compositing. Some shoals may be sampled at several locations and these samples composited for one analysis. Equal aliquots of sediment will be collected from samples to be composited. When all samples for a composite have been collected and placed into the same stainless steel pan, the sample will be stirred and homogenized until a consistent color and texture is achieved.

Sufficient homogenized sample will be prepared to provide adequate volume for laboratory analyses. Physical and chemical samples will be taken from the same homogenate. Portions of each composite sample will be placed in appropriate containers. Each sample container will be clearly labeled and appropriate notations entered into the field book.

4.8 Field Replicates. Blind field replicates will be prepared and submitted along with the rest of the samples to the NPD laboratory. A total of 4 replicates for chemical analyses will be selected from sediments collected from the Willamette River. This represents about 10% of the total samples collected in the Willamette River. One sample shall represent material collected from the deep cores at RM 11 the other three will be collected from locations determined in the field from the mouth to RM 11. Sample numbers shall be WR-A, B, C, or D. Replicate sample locations shall be documented in the field log.

4.9 Sample Transport and Chain-of-Custody Procedures. After sample containers have been filled they will be packed on iced in coolers. Chain-of-custody procedures will commence in the field and will track delivery of the samples. Sample holding times and storage requirements are presented in table 3. Specific procedures are as follows:

- Samples will be packaged and shipped in accordance with U.S. Department of Transportation regulations as specified in 49 CFR 173.6 and 49 CFR 173:24 or delivered directly to the NPD materials Testing Laboratory.
- Individual sample containers will be packed to prevent breakage.
- The coolers will be clearly labeled with sufficient information (name of project, time and date container was sealed, person sealing the cooler and office name and address) to enable positive identification.
- A sealed envelope containing chain-of-custody forms will be enclosed in a plastic bag and taped to the inside lid of the cooler.

Upon transfer of sample possession to the laboratory, the chain-of-custody form will be signed by the persons transferring custody of the coolers. Upon receipt of samples at the laboratory, the coolers will be inspected and the condition of the samples will be recorded by the receiver.

Table 3. Sample Volume and Storage

Sample Type	Holding Time	Sample Size[a]	Temperature[b]	Container	Archive[c]
Particle Size	6 Months	200g	4°C	1-Liter Glass (combined)	X
Total Solids	14 Days	125g	4°C		
Total Volatile Solids	14 Days	125 g	4°C		
Total Organic Carbon	14 Days	125 g	4°C		
Metals (except Mercury)	6 Months	50 g	4°C		
Semivolatiles, Pesticides and PCBs	14 Days until extraction 1 Year until extraction 40 Days after extraction	150 g	4°C -18°C 4°C		
Mercury	28 Days	5 g	-18°C	125 ml Glass	
Volatile Organics	14 Days	100 g	4°C	2-40 ml Glass	

a. Required sample sizes for one laboratory analysis. Actual volumes to be collected have been increased to provide a margin of error and allow for retest.
b. During transport to the lab, samples will be stored on blue ice.
c. A minimum 250 ml container is filled and frozen to run any or all of the analyses indicated.
d. Containers will be completely filled with no headspace allowed.

5.0 LABORATORY PHYSICAL AND CHEMICAL SEDIMENT ANALYSIS

5.1 Laboratory Analyses Protocols. Laboratory testing procedures will be conducted in accordance with the PSDDA Evaluation Procedures Technical Appendix, June 1988; the PSDDA Phase II Management Plan Report, September 1989; and with the PSEP Recommended Protocols except as amended by this sampling plan. The samples will be analyzed for all the parameters listed in Appendix C and requested on the chain-of-custody record. Physical analysis will be conducted by the NPD Materials Testing Laboratory. All chemical analyses will be conducted by private contract analytical chemical laboratories.

5.1.1 Chain-of-Custody. A chain-of-custody record for each set of samples will be maintained throughout all sampling activities and will accompany samples and shipment to the laboratory. Information tracked by the chain-of-custody records in the laboratory include sample identification number, date and time of sample receipt, analytical parameters required, location and conditions of storage, date and time of removal from and return to storage, signature of person removing and returning the sample, reason for removing from storage, and final disposition of the sample.

5.1.2 Limits of Detection. Detection limits of all chemicals of concern must be below screening levels. All reasonable means, including additional cleanup steps and method modifications, will be used to bring all limits-of-detection below the screening levels. In addition, an aliquot of each sediment sample for analysis will be archived and preserved at -18 C for additional analysis if necessary. Sediments or extracts will be kept under proper storage conditions until the chemistry data is deemed acceptable.

5.1.3 Sediment Chemistry. All chemical analyses will be conducted by private analytical laboratories under contract with the NPD Material Testing Laboratory.

5.1.4 Sediment Conventionals. Physical parameters will be analyzed by the NPD Material Testing Laboratory. Particle grain size distribution for each sample will be determined. Sieve analysis will used a geological sieve series which will include the sieve sizes U.S. No. 5, 10, 18, 35, 60, 120, and 230. Hydrogen peroxide will not be used in preparations for grain-size analysis. Hydrometer analysis will used for particle sizes finer than the 230 mesh. Water content will be determined using ASTM D 2216. Sediment classification designation will be made in accordance with U.S. Soil Classification System, ASTM D 2487.

5.1.5 Holding Times. To the maximum extent practicable all chemical results will be provided within 28 days of receipt. All samples for physical and chemical testing will be maintained at the testing laboratory at the temperatures specified in Table 3 and analyzed within the holding times shown in the table.

5.1.6 Quality Assurance/Quality Control. The chemistry QA/QC procedures found in Table 4 will be followed.

5.2 Laboratory Written Report. A written report will be prepared by the analytical laboratory documenting all the activities associated with sample analyses. As a minimum, the following will be included in the report:

- Results of the laboratory analyses and QA/QC results.
- All protocols used during analyses.
- Chain of custody procedures, including explanation of any deviation from those identified herein.
- Any protocol deviations from the approved sampling plan.
- Location and availability of data.

As appropriate, this sampling plan may be referenced in describing protocols.

Table 4. Minimum Laboratory QA/QC

Analysis Type	Method Blank[2]	Duplicate[2]	RM[2,4]	Matrix Spikes[2]	Surrogates[7]
Semivolatiles[1]	X	X[3]	X[5]	X	X
Pesticides/PCBs[1]	X	X[3]	X[5]	X	X
Metals	X	X	X[6]	X	
Total Organic Carbon	X	X	X[6]		
Total Solids		X			
Total Volatile Solids		X			
Particle Size		X			

1. Initial calibration required before any samples are analyzed, after each major disruption of equipment, and when ongoing calibration fails to meet criteria. Ongoing calibration required at the beginning of each work shift, every 10-12 samples or every 12 hours (whichever is more frequent), and at the end of each shift.
2. Frequency of Analysis = one per batch
3. Matrix spike duplicate will be run
4. Reference Material
5. Canadian standard SRM-1
6. NIST certified reference material 2704
7. Surrogate spikes will be included with every sample, including matrix-spiked samples, blanks and reference materials

6.0 BIOLOGICAL TESTING

6.1 Biological Testing. No biological testing will be conducted under this study, however the need for biological testing will be assessed per the RDMTM.

7.0 REPORTING

7.1 QA Report. The NPD Material Testing Laboratory will prepare a quality assurance report based upon a review of the contract laboratory analytical data. The laboratory QA/QC reports will be incorporated by reference. This report will identify any laboratory activities that deviated from the approved protocols and will make a statement regarding the overall validity of the data collected.

7.2 CRCD EIS. A written discussion of findings shall be prepared documenting the physical and chemical character of potential material to be dredged as part of the CRCD EIS. The physical and chemical reports will be included as reference, individual copies will be furnished as requested. As a minimum, the following will be included in the EIS:

- Previous sampling and analyses.
- Locations where the sediment samples were collected.
- A plan view of the project showing the actual sampling location.
- Description of sampling and compositing procedures.
- Chemical testing data, with comparisons to screening levels guidelines.

APPENDIX A

HISTORIC PERSPECTIVE, MAPS, AND SHOAL DESCRIPTIONS

CURRENT MAINTENANCE DREDGING IN THE COLUMBIA RIVER

HISTORICAL PERSPECTIVE

The Columbia River rises in British Columbia, through which it flows for 425 miles. It enters the United States in northeastern Washington, and empties into the Pacific Ocean. Total length of river is 1,210 miles. The Willamette River rises in the Cascades Range in western Oregon, flows northerly, and empties into the Columbia River about 100 miles from the sea. Its length from source of the Middle Fork is about 294 miles. Dredging is primarily concentrated in those reaches from the mouth to about RM103.5 on the Columbia and to RM 11.1 on the Willamette along with several side channels, marinas, and docking facilities.

The navigation channel from the mouth of the Columbia River to Portland, Oregon was first approved in 1877. In 1882 a 30-foot entrance channel was approved. It wasn't until 1894 that the first extensive channel dredging occurred. In 1905 a 40-foot entrance channel was initiated, by 1917 the north jetty was completed and the channel stabilized below 40-foot. Fourteen million cubic yards were removed in 1956 during constructing of a 48-foot entrance channel. In 1977, 9 million cubic yards of material was removed during the construction of an authorized 52-foot entrance. The entrance channel was deepened to its present authorized depth of 55 feet between 1984 and 1986. Since 1956, approximately 160 million cubic yards of sand have been dredged from the entrance channel with an annual average of 4.1 million cubic yards. All material is removed by hopper dredge and placed at ocean disposal sites.

In 1899 the navigation channel to Portland was authorized to 25-foot. This was increased to 30-foot in 1912. Construction beginning in 1914 with extensive dredging and pile dike construction. There was also extensive filling of the water front in Astoria, Oregon. The Columbia River channel was authorized to 35-foot in 1930 with construction completed in 1935. This provided the present channel configuration and established the pile dike system. The present 40-foot channel was authorized in 1962 with construction completed in 1976.

DESCRIPTIONS OF SHOALS DREDGED

RM 3.0 to 21.4

DESDEMONA SHOAL

Project Description: The lower shoal lies between RM 5.0 and RM 8.0 extending into the channel from the Oregon side. The upper shoal lies between RM 8.7 and RM 9.4 and is on the Washington side of the channel. These shoals generally do not extend across the width of the channel.

Maintenance: The Desdemona Shoal is used as foul weather backup work for dredging equipment working at the MCR project. This is usually sufficient to keep the channel clear in this reach. There are very steep cutbacks on channel slopes. Caution in this area has been necessary to avoid either grounding hopper dredges or damaging drag arms. This area has been hopper dredged from 1986 to 1988. The maximum quantity dredged was in 1987 at 193,000 cy and the minimum dredged was 13,000 cy. The average is 84,000 cy. In FY 1992 5,104 cy of sediment was removed by hopper dredge. In FY 1994 the channel was dredged twice with a total of 74,170 cy of sediment hopper dredged and disposed at Desdemona Shoal site "D" and on the Washington side of the channel. In FY 1995 (October 1994), 236,896 cy of sediment was hopper dredged and disposed on the Washington side of the channel.

FLAVEL BAR

Project Description: This reach has sever shoaling and lies between RM 11.0 and RM 13.4. The shoaling reaches across the full width of the channel, caused by the cross-currents form Youngs Bay and the encroachment of Desdemona Sands.

Maintenance: This area is critical for commercial navigators since transit is during low tide and is required to a depth of -45 MLLW. Maintenance is primarily by hopper dredges and is often foul weather backup work for equipment working the MCR project. An annual average of 313,800 cy was dredged form the reach from 1986 to 1990. In FY 1990, 248,463 cy of sediment was hopper dredged. In FY 1991, 183,047 cy of sediment was hopper dredge. In FY 1992 the channel was dredged with both the hopper and pipeline dredges. 360,325 cy was hopper dredged while 185,565 cy was pipeline dredged, totaling 545,890 cy. In 1993 the channel was hopper dredged twice with a total of 950,609 cy of material removed. In FY May 1996, 263,126 cy of sediment was hopper dredged and was disposed at the Flavel Bar, chart 3 on the Oregon side of the channel.

UPPER SANDS

Project Description: Shoaling in this reach of the river occurs across the channel between RM 16.0 and RM 17.0.

Maintenance: Hopper dredges perform the channel maintenance; Upper Sands is often used as relief work when weather makes dredging unsafe on the MCR project. A total of 183,100 cubic yards of material was removed in 1988. Most of the material is placed at the Harrington Point Sump with some going to Site D. In FY 1993 (October and November 1992), 684,501 cy of sediment was hopper dredge and disposed at Upper Sands on the Washington side of the channel. In FY 1996 (October 1995), 60,431 cy of sediment was hopper dredge and disposed of at Harrington Point Sump.

TONGUE POINT CROSSING

Project Description: The flows in this reach disperse across Taylor Sands and trough Prairie North Channel. This dispersion tends to reduce flows in the upstream reach of this stretch of the river, inducing shoaling. The Tongue Point Crossing reach has shoaling in two locations. One shoal occurs between RM 18.7 and RM 19.1, crossing the channel from the Washington side of the cut. The other shoal, upstream at RM 20.2, is on the Oregon side of the channel.

Maintenance: Between 1986 and 1990, the annual average dredging volume was 162,400 cubic yards dredged by hopper. The Tongue Point Crossing has also been used as foul weather backup for equipment working the MCR project. The main disposal site for material is at the Harrington Sump; from there it is re-handled to Rice Island by pipeline dredges. In FY 1990, 904,300 cy was removed by clamshell and disposed at MCR site "F". In FY 1991, the channel was hopper dredged twice and totaled 432,830 cy of material. In FY 1992, the channel was dredged three times and totaled 402,948 cy. In FY 1993, the channel was dredged three times; twice with hopper dredges that totaled 300,720 cy and once by pipeline dredge and totaled 193,621 cy. The total dredge was 494,341 cy. In FY 1994, the channel was dredged twice by hopper dredge and totaled 662,973 cy and was disposed at Miller Sands and Harrington Point Sump. In FY September 1995, 150,192 cy of sediment was hopper dredged and disposed at Harrington Point Sump. In FY June and July 1996 the channel was hopper dredged twice totaling 176,749 cy and disposed at Harrington point Sump.

Dredged Material Description for the Reach

The bulk of the material dredged from this reach consists of clean medium to fine sands. Fines and organic content are less than one percent by weight.

RM 21.4 to 29.4

MILLER SANDS CHANNEL

Project Description: There are two main shoals. The Lower Miller Sands Bar extends along the Oregon side form RM 21.4 to RM 22.5. The Upper Miller Sands Bar extends along the Oregon side form RM 23.5 to RM 24.6.

Maintenance: Hopper dredges maintain the reach intermittently form March to October, transporting material to the Harrington Point Sump disposal site. That material is later re-re-handled by pipeline dredge and placed at Miller Sands Island or Rice Island, usually during May. The majority of the reach is pipeline dredged. The average annual quantity dredged by pipeline and hopper from 1986 to 1990 was 397,200 cy and 147,200 cy respectively. In FY 1990 the channel was dredged twice by both hopper and pipeline dredges. The hopper dredged 85,536 cy while the pipeline dredge 194,741 cy, totaling 280,277 cy. In FY 1991, the channel was dredged with both a pipeline and hopper dredged. The hopper dredged 153,513 cy while the pipeline dredged 239,011, totaling 392,524 cy. Also the material was re-handled form the Harrington point Sump with a pipeline dredge that removed 468,663 cy. Also the sediment was re-handled by a pipeline dredge and removed 734,184 cy of sediment from the Harrington Point Sump. IN FY 1992, the channel was dredged three times . Twice with hopper dredges, and once with a pipeline dredge. The hopper dredges removed a total of 147,820 cy, while the pipeline dredged 436,363 cy, totaling 584,183 cy of sediments. In FY 1993, 354,268 cy was pipeline dredged. In FY 1994, 1,140,749 cy was pipeline dredged. In FY July and August 1995, 469,905 cy of sediment was pipeline dredged and disposed upland at Miller Sands on the Washington side of the channel, and was also disposed on the Oregon side for beach nourishment. In FY April, May and September 1996, the channel was hopper and pipeline dredged. 80,174 cy was hopper dredged and disposed at Harrington Point Sump and Miller Sands on the Washington side of the channel, while 236,325 cy was pipeline dredged and disposed at the Miller Sands on the Oregon side of the channel for beach nourishment. Totaled dredged was 316,499 cy.

PILLAR ROCK RANGES

Project Description: There are two shoals on the Oregon side. The main bar is the Upper Pillar Rock Bar which extends from RM 26.4 to RM 27.9. Downstream a shoal lies between RM 25 to RM 26. Shoaling is caused by side slope adjustment and erosion from Pillar Rock Island disposal areas. These ranges are a part of the LTMS study area.

Maintenance: The Pillar Rock Ranges are dredged annually by hopper and pipeline dredges. The annual average quantity for hopper from 1986 to 1990 was 196,000 cy, while the pipeline was used only in 1988. In FY 1990, 166,469 cy was hopper dredge. In FY 1992 45,107 cy was hopper dredged. In FY 1993 the channel was dredged twice by pipeline dredged, totaling 171,506 cy. In FY 1994 95,031cy of sediment was hopper dredged. In FY 1995 (March and August), the channel was dredged twice by hopper dredge, totaling 273,401 cy and was disposed at Pillar Rock Ranges on the Washington side of the channel. In FY July 1996, 35,539 cy was hopper dredged and disposed at the Harrington Point Sump.

Dredged Material Description for the Reach

The bulk of the material dredged from this reach consists of clean medium to fine sands. Fines and organic content are less than one percent by weight.

RM 29.4 to 48.4

BROOKFIELD - WELCH ISLAND REACH

Project Description: There are two shoals. The downstream shoal, the Lower Brookfield - Welch Island Bar extends form RM 29.4 to RM 30 along the Oregon edge of the channel. The upstream shoal extends from RM 31.4 to RM 32.2 along the Oregon edge of the channel on the inside bend of the river's natural channel.

Maintenance: Dredging in this area has decreased since realigning the channel 300 feet to the south and reducing the length of the pile dike by 100 feet at RM 29 on the Washington side. A pipeline dredge was used in 1986 and 1990 with an average of 287,000 cy. A hopper dredge was used in 1987 for 49,000 cy of sediment. In FY July 1990 259,395 cy was pipeline dredge and was disposed at Pillar Sands and at Brookfield on the Washington side. In FY 1993 (November 1992), 56,727 cy was hopper dredge and disposed at Miller Sands and Pillar Rock Ranges. In FY 1994, the channel was dredged by both the hopper and pipeline dredges. The hopper dredged 100,069 cy in May 1994 and the pipeline dredged 274,855 cy, totaling 374,924 cy. These we disposed at Brookfield-Welch Island. In FY June and July 1995 the channel was dredge by both the hopper and pipeline dredged. 37,699 cy of hopper dredged while 327,213 cy was pipeline dredged. These were disposed in the Brookfield-Welch Island and also on the Oregon side of the channel. In FY March, May, June, July and August 1996, 332,975 was hopper dredged and disposed at the Brookfield-Welch Island on the Washington side of the channel.

SKAMOKAWA BAR

Project Description: The Skamokawa bar reach of the navigation channel has shoaling at two locations. Welch Island Bar extends from RM 32.6 to RM 34.0 along the Oregon side of the channel. In the mid - 1980's the Oregon side was widened and the shoals have required little dredging. Skamokawa Bar lies between RM 35.0 to RM 35.9 on the Oregon side.

Maintenance: Hopper and pipeline dredges maintain these bars. The hopper dredge quantity averaged 60,000 cy in 1986 and 1987. The pipeline dredge has operated from 1986 to 1989, averaging 318,000 cy. In FY 1991 (July 1991 and October 1992) the channel was dredged by hopper and pipeline dredge. 172,969 cy was hopper dredged and disposed at the Skamokawa Bar on the Washington side of the channel. 217,859 was pipeline dredged and disposed at the Skamokawa Bar on the Oregon side of the channel. In FY July 1992 535,443 cy of sediment was pipeline dredged and disposed upland at Skamokawa Bar on the Washington side of the channel. In FY March, July and August 1994 the channel was dredged by hopper and pipeline. 260,500 cy was pipeline dredge and disposed an-water at Skamokawa Bar on the Oregon side of the channel. 29,422 cy was hopper dredged and disposed at the Skamokawa Bar on the Washington side of the channel. These totaled 289,922 cy. In FY August to September 1995, 187,916 cy was hopper dredge and was disposed in-water at the Skamokawa Bar on the Washington side of the channel. In FY 1996, (August to September 1995), 292,686 cy of sediment was removed by hopper dredged and was disposed at Skamokawa Bar.

PUGET ISLAND BAR

Project Description: There is one major shoal in this reach of the river. It lies between RM 37.4 to RM 38.7.

Maintenance; The Puget Island Bar has been dredged during 1986 to 1990, three of the five years by hopper dredge and three of five years by pipeline dredge. The five year average annual quantity for the reach is 213,800 cy. In 1990, 109,398 cy of material was pipeline dredged. In FY 1992, 151,773 cy of sediment was pipeline dredged. In 1992, 49,556 cy of sediment was hopper dredged. In FY 1993 the channel was dredged twice by hopper dredge totaling 373,228 cy. In FY 1994 210,803 cy of sediment was dredged and disposed at the Puget Island bar on the Washington side of the channel. In FY 1996 (October 1995, March and June 1996) 708,808 cy of sediment was hopper dredged and disposed at the Puget Island bar on the Washington and Oregon side in October,

WAUNA - DRISCOLL RANGES

Project Description: This range includes the Lower Westport Bar. This stretch of the river channel has three shoaling areas. Frequent dredging has been required in this area. Coffeepot Island was built as a flow control structure and has reduced the maintenance in the channel parallel to it. However, shoaling still occurs downstream of the island at Wauna Bar. Shoaling occurs at RM 43 on the Washington side near the upper end of the island. The upper segment of the Wauna - Driscoll Range is a continuance of extensive shoaling from RM 47.6 where the river separates onto two channels around Puget Island (Middle Westport Bar).

Maintenance: The Wauna - Driscoll Range has been maintained by hopper dredge, removing an annual average quantity of 211,300 cy form 1986 to 1989. Pipeline dredges have been used in 1986, 88, and 90 with an average of 299,300 cy of sediment removed. In FY 1990, 204,044 cy of sediment was pipeline dredged. In FY 1991 the channel was dredged by both the hopper and pipeline dredge. 106,257 cy was pipeline dredge and 336,221 cy was hopper dredge; totaling 442, 221 cy. In FY 1993 151,129 cy was pipeline dredged. In FY 1994 263,023 cy was hopper dredged. In FY June 1996 206,794 cy was hopper dredged and disposed at Wanua-Driscoll Ranges on the Washington side of the channel. In FY 1996 (October and November 1995), 455,901 cy was pipeline dredged and disposed on-water at Puget Island Bar on the Washington side of the channel and in several locations at the Wanua-Driscoll Ranges, both in-water and upland on the Oregon and Washington side of the channel.

WESTPORT BAR

Project Description: The Westport Bar is one of the most troublesome bars along the navigation channel. More than three miles of this segment shoals. The downstream shoal is an extension of the shoaling that occurs in the upstream segment of the Wanuna - Driscoll Range. The shoal extends from RM 44.4 to 45.4 on the Washington side. The second shoal extends from the Washington side of the channel to the Oregon side between RM 45.7 to RM 46.7. The upper Westport Bar is the most active shoal in this reach and extends from RM 46.8 upstream to RM 48.4.

Maintenance: The bars have been maintained by hopper and pipeline dredged. The average from 1986 to 1990 for the hopper dredge is 166,600 cy. The average pipeline dredge for 1986, 89, and 90 is 439,000 cy of sediment. In FY 1990, the channel was dredged by hopper and pipeline. 134, 223 cy was hopper dredged and 198,210 cy was pipeline dredge; totaling 332,433 cy. In FY 1991, the channel was dredged three times, twice by hopper dredge and once by pipeline dredge. 256,224 cy was hopper dredged, 33,720 cy was pipeline dredged; totaling 389,944 cy. In FY 1992, 284,446 cy was hopper dredged. In FY 1993 the channel was dredged four times, once with a pipeline dredged while the remaining three were hopper dredged. 693,919 cy was pipeline dredged and 285,277 was hopper dredged; totaling 979,196 cy. In FY 1994, 37,100 cy of sediment was hopper dredge. In FY August 1995, 717,747 cy was pipeline dredged and disposed in several location at the Westport Bar on the Oregon and Washington side of the channel for upland and beach nourishment . 108,584 cy of material was hopper dredged and was disposed at he Westport bar on the Oregon side of the channel. In FY 1996 (October 1995, May, June and August 1996, the channel was hopper and pipeline dredged. 88,495 cy was hopper dredged and 944,446 cy was pipeline dredged; totaling 1,032,941 cy and was disposed mostly at the Westport Bar and at the Eureka Bar all for beach nourishment.

Dredged Material Description for the Reach

The bulk of the material dredged from this reach consists of clean medium to fine sands. Fines and organic content are less than one percent by weight.

RM 48.4 to 80.3

EUREKA ISLAND

Project Description: The Eureka Bar reach experiences shoals at two locations. The Lower Eureka Bar runs from RM 49.9 to RM 50.5 on the Oregon side of the channel. The main Eureka Bar extends from RM 51.4 to RM 52.0, also predominately on the Oregon side of the channel. However, shoaling has sometimes covered the width of the entire channel for a short distance. Some natural scouring is promoted by the disposal island and pile dikes between the two shoaling areas.

Maintenance: Eureka Bar is primarily maintained by hopper dredge. Between 1986 and 1990 the project was dredged 3 of the 5 years with 73,000, 15,000 and 75,000 cubic yards dredged per year. In FY 1991 75,282 cy of material was pipeline dredged. In FY 1993 27,065 cy was hopper dredged. In FY 1994, 24,775 cy was hopper dredged and disposed at the Eureka Bar. In FY September 1996 62,019 cy was hopper dredged and was disposed at the Eureka Bar on the Washington side of the channel.

GULL ISLAND BAR

Project Description: The Gull Island reach is relatively well maintained by natural processes. One shoal exists which extends from RM 54.1 to EM 54.8 on the Oregon side.

Maintenance: The shoal has been hopper dredged from 1986 to 1990, averaging 100,400 cy annually. In 1987 the shoal was also pipeline dredged 172,000 cy of sediment. In FY 1990, 130,0505 cy was hopper dredged. In FY 1995 (November 1994), 138,488 cy was hopper dredged and disposed at the Gull Island bar on the Washington side of the channel. In FY August 1996, 59,868 cy was hopper dredged and disposed at the Gull Island Bar on the Washington side of the channel.

STELLA - FISHER BAR

Project Description: Stella Bar extends from RM 56.3 to RM 57.8 along all of the Oregon side and most of the Washington side. Flow control structures along the Oregon side hasn't reduced much of the shoaling in this reach. Fisher Bar lies between RM 58.1 and 59.4 on both the Washington and Oregon sides of the channel.

Maintenance: Pipeline dredge has been used for 1986 to 1989 while the hopper dredge was used in 1986, 1988, and 1989. The average annual quantity dredged is 297,600 cy. In 1990, the channel was dredged by hopper and pipeline dredge. 340,390 cy was hopper dredge and 553,684 cy was pipeline dredged; totaling 894,074 cy. In FY 1991 the channel was dredged three times, twice with hopper dredges and once with a pipeline dredge. 98,614 cy was hopper dredged and 229,865 was pipeline dredged; totaling 328,479 cy. In FY 1992, 445,594 cy was pipeline dredged. In FY 1993, the channel was hopper and pipeline dredged. 508,036 cy was hopper dredged and 245,919 was pipeline dredged; totaling 753,955 cy. In FY 1994, 79,597 cy was pipeline dredged. In FY march, July and August 1995, the channel was hopper and pipeline dredged. 181,982 cy was hopper dredged and disposed at the Stella-Fisher Bar on the Washington side of the channel while 103,025 cy of sediment was pipeline dredged and disposed at the Stella-Fisher Bar. These totaled 285,007 cy. In FY June and July 1996, 856,729 cy pipeline dredged and disposed at the Stella-Fisher Bar on the Washington and Oregon side of the channel for beach nourishment.

WALKER ISLAND REACH

Project Description: Walker Island Bar extends from RM 59.9 to RM 60.5 and along the Oregon side. The Lord Island Bar is a minor shoal that is located from RM 62.75 to RM 63.3 and usually forms on the Oregon side. Flow control structures has reduced the shoaling in this reach.

Maintenance: Hopper and Pipeline dredged have been used to dredge this reach. Hopper dredge has been used in 1987 and 1989 while pipeline dredge was only used in 1986. The average quantity of sediment dredged is 163, 300 cy. In FY August 1996, 51,272 cy was hopper dredged and disposed at the Walker Island Reach.

SLAUGHTERS BAR

Project Description: Areas of seasonal shoaling include a bar across the channel that develops from RM 63.6 to RM 64.37 and a shoal on the Washington side near RM 65. Sand wave shoaling develops upstream of the Lewis and Clark Bridge between Longview, WA and Rainer, OR related to sediment carried into the Columbia from the Cowlitz River.

Maintenance: The reach received heavy deposits from Mount St. Helens' eruption requiring millions of cubic yards dredged from the channel for five years following that event. By 1986, the channel had stabilized. In that year, dredging operations returned to normal maintenance levels. In 1990, 203,658 cy was hopper dredged. In FY 1991 the channel was dredged by hopper and pipeline dredge, 187,058 cy was hopper dredge and 185,600 cy was pipeline dredged; totaling 372,658 cy. In 1992, 455,194 cy was hopper dredge. In FY 1993 the channel was hopper and pipeline dredged. 283,294 cy was hopper dredge and 45,928 was pipeline dredged; totaling 329,222 cy. In FY 1994, 33,643 cy was hopper dredged. In FY 1995 (October and November 1994, June and August 1995), the channel was dredged three times, twice by hopper dredge and once pipeline dredged. 453,222 cy, was hopper dredged 372,035 cy was pipeline dredged; totaling 825,257 cy. In FY March and June 1996, 226,460 cy was hopper dredged and was disposed at Slaughters Bar and Walker Island Reach on the Oregon side of the channel.

LOWER DOBELBOWER REACH

Project Description: Shoaling is minimal in this segment of the channel.

Maintenance: Before the Mount St. Helens eruption, the Lower Dobelbower Bar required maintenance infrequently. Hopper dredges were used in 1987 and 89 while the pipeline dredge was used in 1986, 1987 and 1990. The average amount of sediment dredged is 210,600 cy. In FY 1990, the channel was dredged twice with hopper and pipeline dredges 22,008 cy was hopper dredged and 219,815 was pipeline dredged, totaling 241,823 cy. In FY 1991, 241,208 cy as pipeline dredge. In 1993, the channel was dredged by hopper and pipeline dredge. 119,047 cy was hopper dredged and 456,724 cy was pipeline dredged; totaling 575,771 cy of sediment. In 1994, 105,549 cy of sediment was removed by hopper dredge. In FY 1995 (October 1994, June and September 1995), 134,980 cy by hopper dredged and disposed at the Lower Dobelbower Bar and the Slaughter bar on the Oregon side of the channel. In FY January, February and, August 1996, was both hopper and pipeline dredged. 39,604 cy of sediment was hopper dredged and disposed at the Lower Dobelbower Bar while 176,730 cy was pipeline dredged and disposed at Slaughter Bar

UPPER DOBELBOWER BAR

Project Description: By 1987 the channel in the reach had been stabilized from the aftermath of the Mount St. Helens eruption. Over 24 million cy of sediment had been dredged from the Upper and Lower Dobelbower reaches to re-establish the channel.

Maintenance: Hopper and pipeline dredges have been used to maintain the channel. The hopper dredge was used in 1987 and 1988 while the pipeline dredge was used in 1986, 1988 and 1989. In 1988 1,016,000 cy of material was dredged by pipeline dredge. The average quantity dredged is 338,600 cy. In FY 1988 the channel was hopper ad pipeline dredged. 1,015,920 cy was pipeline dredged and 82,750 cy was hopper dredged. In FY 1989 132,632 cy of sediment was pipeline dredged. In FY 1994 132,112 cy was pipeline dredged. In FY March and September 1995, 222,476 cy hopper dredged and disposed at the Upper Dobelbower Bar on the Washington and Oregon sides.

KALAMA RANGES

Project Description: There are two shoals in this reach. The Lower Kalama Bar extends form RM 73.9 to RM 74.8 along the Oregon side. The Upper Kalama Bar shoal extends from RM 75.3 to RM 76.7 along the outer edges of Washington and Oregon sides.

Maintenance: The flow control structure at Kalama and at the upper end of the Sandy Island on the Oregon shoreline has reduced dredging. The hopper dredge was operated in 1986, 87, and 88 and the amount averaged 166,000 cy of material. The pipeline dredge was operated in 1986, 87, and 90 and averaged 235,700 cy of material. In FY 1990, 96,825 cy was pipeline dredged. In FY 1991, 296,775 cy was hopper dredged. In FY 1992, 218,361 cy was pipeline dredged. In 1993, 99,300 cy was hopper dredged. In 1994, 19,870 cy was hopper dredged and disposed at Kalama Bar on the Washington. In FY 1995 (October 1994 and September 1995), 258,949 cy was removed by hopper dredge and disposed of at the Kalama Bar on the Washington side of the channel, Lower Dobelbower Bar and Upper Dobelbower Bar on the Washington side of the channel. In FY July, June and August 1996, 219,964 cy was pipeline dredged and 180,277 cy was removed by hopper dredged; totaling 400,241 cy and was upland disposed at the Kalama Bar on the Washington side for upland disposal and on Oregon side of the channel.

Lower Martin Island Bar

Project Description: The reach near Lower Martin Island has only one area of shoaling, a bar that develops from RM 79.2 to RM 80.2 along the Oregon side of the channel. This shoal lies over a submarine crossing for a natural gas line at RM 76.75. For safety, no pipeline dredging occurs over this crossing. Hopper dredges maintain the area, holding drag arm depth to -43 feet, CRD or less.

Maintenance: Hopper dredges have maintained the bar as needed but not yearly, with average annual removal reaching approximately 246, 500 cubic yards. A pipeline dredge was used in 1989 removing 135,000 cubic yards. In 1991, 56,382 cy of sediment was hopper dredged. In FY 1992 the channel was dredged twice by hopper dredge and totaled 369,036 cy. In FY 1993, 273,34 cy was hopper dredged. In FY 1994, 111,943 cy was hopper dredged and disposed at the Lower Martin Island Bar on the Oregon side of the channel. In FY August and September 1995, 136,868 cy was hopper dredged. In FY 1995 (June, July and August 1996), 215,476 cy was hopper dredged and disposed at the Lower Martin Island Bar on the Oregon side of the channel.

Dredged Material Description for the Reach

The bulk of the material dredged from this reach consists of clean medium to fine sands. Fines and organic content are less than one percent by weight.

RM 80.3 to 106.4

UPPER MARTIN ISLAND BAR

Project Description: There are two shoals in this reach. Martin Island Bar extends form RM 80.3 to RM 81.2 on the inside turn of the Columbia River. It is continuous and shoals to depths less tan 40 feet. The upstream, and most significant, of the two shoals is the Upper Martin Island Bar which extends from RM 82.5 to RM 83.8. It is a sand wave formation resulting from bedload sediment transport and deposition.

Maintenance: Hopper dredges has maintained the channel in 1987, 1988, and 1989 and averaging 210,000 cy of material annually. In 1989, 348,000 cy of material was removed by the pipeline dredge. In FY 1992, 156,660 cy was hopper dredged. In FY 1994, 48,592 cy was hopper dredged and disposed at the Upper Martin Island Bar on the Washington side of the channel. In FY June, September 1995, 175,237 cy was hopper dredged an disposed in several locations at the Upper Martin Island Bar. In FY 1996 (October 1995, June, July and August 1996), 249,473 cy was hopper dredged and disposed at he Upper Martin Island Bar.

ST HELENS BAR

Project Description: Shoaling occurs from RM 85.0 to RM 86.6 along the Oregon channel cutline.

Maintenance: Flow control structures along the Washington shoreline has reduced maintenance dredging requirements. It is maintained as needed by hopper and pipeline dredges. In 1987 and 1988 a hopper dredge was used while in 1989 and 1990 a pipeline dredge was used. The average sediment removed with both dredges is 116,250 cy annually. In FY 1990, 193,574 cy was pipeline dredged. In FY 1994, 120,763 cy was pipeline dredged. In FY 1995, 23,758 cy was hopper dredged and disposed at the Saint Helens Bar. In FY October and August 1996, 171,564 cy was hopper dredged and disposed at the Saint Helens Bar on both the Oregon an Washington side of the channel.

WARRIOR ROCK BAR

Project Description: Two shoaling areas exist on this reach. The lower Warrior Rock is minor and extends from RM 87.7 t RM 88.0 on the Washington Side. The Upper Warrior Rock Bar extends from RM 89.6 to RM 91.4, across the full width of the channel.

Maintenance: A hopper dredge has worked in the area in each or the five years averaging removal of 206,200 cy annually. The last use of a pipeline, in 1985, removed 184, 00 cy. In FY 1990, 39,448 cy was hopper dredge. In FY 1992, 79,317 cy was hopper dredged. In FY 1993, 219,265 cy was hopper dredged. In FY 1994, 100,419 cy was hopper dredged and disposed at the Warrior Rock on the Oregon side of the channel. In FY March and September 1995, 48,325 cy was hopper dredged and disposed at the Warrior Rock on the Oregon side of the channel. In FY1996 (March, September 1995and July 1996, 104,536 cy was hopper dredged and disposed at Warrior Rock on both the Oregon and Washington side of the channel.

HENRICI BAR

Project Description: The Henrici Bar reach has two locations where shoals form and require dredging. The shoal at Henrici Bar extends form RM 90.4 upstream to RM 91.5 and is an extension of the Upper Warrior Rock Bar. The bar is created by sand wave movement, resulting in shoaling of the full width of the channel. The second shoal is at Lower Willow Bar, it is minor compared with others on the river.

Maintenance: Hopper dredges have maintained the area from 1986 to 1990, with the average removal of 205,200 cy annually. A pipeline dredge was used in 1985 removing 184,300 cy of material. In FY 1990, 35,000 cy of sediment was hopper dredged. In FY 1992 the channel was dredge twice both by hopper dredge, totaling 428,698 cy. In FY 1993 284,059 cy was removed by hopper dredge. In FY March, June July and August 1995, the channel was hopper and pipeline dredged. 144,612 cy was hopper dredged while 192,054 cy was pipeline dredged;

totaling 336,666 cy and was dispose in several locations at the Henrici bar on the Oregon and Washington sides of the channel. In FY October 1996, 9,790 cy was hopper dredged and disposed at the Henrici Bar.

WILLOW BAR

Project Description; Significant shoaling occurs in this reach. It extends from RM 95.5 to RM 97.6, occurring along both edges of the channel until the upstream end, where it extends across the width of the channel.

Maintenance: This reach has been maintained by hopper dredge from 1986 to 1990 with an average of 98,700 cy of sediment annually. A pipeline dredge was also used during 1986 and it removed 131,000 cy of sediment. In 1990, 4,800 cy was hopper dredged. In 1992, 63,106 cy was hopper dredged. In FY 1993, 17,840 cy was hopper dredged. In FY 1994 829,744 cy was hopper dredged. In FY June ad August 1995, 103,346 cy was hopper dredged. and disposed at the Willow bar on both the Oregon and Washington side of the channel. In FY June, July, October, March and June 1996, 274,646 cy was hopper dredged and was disposed at the Willow Bar on the Washington side of the channel.

Morgan Bar

Project Description: Three distinct shoals occur within the Morgan Bar reach. Furthermost downstream is an extension of the Willow Bar. The second shoal, Lower Morgan Bar, extends from RM 98.2 upstream to RM 99.0. Shoaling occurs on the Washington side as the channel attempts to migrate towards the south. Pile dikes placed at Sauvie Island and along the Oregon shoreline attempt to stabilize and control the channel. The major shoaling site in the reach extends from RM 99.3 upstream to RM 100.1. This shoal, Upper Moragn Bar, can reduce channel depth across the entire navigation channel.

Maintenance: Between 1986 and 1990 the reach was dredged three times in five years. Annual volumes were relatively constant at 20,000 to 21,000 cubic yards dredged by hopper dredge. The Oregon side of the channel from RM 100 the RM 101 is an in-water disposal area for material from Willamette River maintenance activities. In FY January 1990, 19,800 cy was hopper dredged and disposed at the Morgan Bar on the Oregon side of the channel. In FY October 1991, 21,500 cy was hopper dredged and disposed at the Morgan Dike. In FY October 1996, 29,788 cy was hopper dredged and disposed at the Morgan Bar on the Oregon side of the channel.

LOWER VANCOUVER BAR

Project Description: The potential for shoaling covers a large area in this reach, but individual shoals actually form in limited sections at any given time. Shoaling does not occur every year.

Maintenance: Dredging is infrequent. In 1987 the hopper dredge removed 7,000 cy of sediment while the pipeline dredge removed 300,000 cy of sediment. In June 1996 49,630 cy was hopper dredged on disposed at the Morgan Bar on the Oregon side of the channel.

VANCOUVER TURNING BASINS

Project Description: The authorized project provides a channel 40 feet deep and 500 feet wide from RM 101.4 to RM 104.6; a lower turning basin 40 feet deep, 800 feet wide, and 5,000 feet long; and an upper turning basin 35 feet deep, 800 feet wide, and 2,000 feet long just before the Interstate Bridge at RM 106.5.

Maintenance: The upper basin, from the railroad bridge to the Interstate 5 bridge, is maintained to a depth of 35 feet and in 1988, 303,000 cy of sediment was removed by pipeline dredge. The lower basin, downstream from the railroad bridge, is maintained to a depth of 40 feet and in 1987, 465,000 cy of sediment was removed by pipeline dredge. In 1989 5,000 cy of sediment was removed by hopper dredge but in 1990, 458,000 cy of sediment was removed. The total areas average is 307,800 cy. In 1992, 389,824 cy was pipeline dredged. In FY 1996 (November 1995), 177,657 cy was pipeline dredged and disposed upland at the Vancouver turning basin.

Dredged Material Description for the Reach

The bulk of the material dredged from this reach consists of clean medium to fine sands. Fines and organic content are less than one percent by weight.

APPENDIX B

SAMPLE LOCATIONS AND PROJECT MAPS

Columbia River Channel Deepening
Columbia River Proposed Sample Locations

Sample	Longitude	Latitude	RM	Remarks
CR-BC-1	-123:59:03.3343	46:14:01.9406	6+00	Desdemona Shoal
CR-BC-2	-123:58:40.4168	46:13:53.8876	6+18	Desdemona Shoal
CR-BC-3	-123:58:21.3699	46:13:35.9257	6+40	Off Bouy 22
CR-BC-4	-123:56:00.2036	46:12:12.4797	9+10	Flavel Bar (Chem)
CR-BC-5	-123:54:10.8466	46:11:24.0717	11+00	Flavel Bar
CR-BC-6	-123:53:15.0373	46:11:30.4439	11+40	Flavel Bar
CR-BC-7	-123:52:13.3125	46:11:32.2848	12+30	Flavel Bar
CR-BC-8	-123:51:51.6669	46:11:24.7337	12+45	Flavel Bar (Chem)
CR-BC-9	-123:49:11.7802	46:11:49.6890	15+00	Upper Sands
CR-BC-10	-123:47:34.3607	46:12:26.5769	16+25	Upper Sands
CR-BC-11	-123:45:06.0607	46:13:18.6687	18+35	Toung Pt. X-ing
CR-BC-12	-123:43:34.5881	46:13:49.2555	20+00	Toung Pt. X-ing
CR-BC-13	-123:48:56.1150	46:17:08.7026	20+50	Toung Pt. X-ing
CR-BC-14	-123:41:32.6230	46:14:51.4486	22+00	Toung Pt. X-ing
CR-BC-15	-123:39:27.5695	46:15:23.5588	23+40	Miller Sands (L side)
CR-BC-16	-123:38:17.4846	46:15:35.0619	24+40	Miller Sands
CR-BC-17	-123:35:14.5464	46:15:22.4087	27+10	Piller Rock
CR-BC-18	-123:33:31.3486	46:15:26.9171	28+30	Piller Rock
CR-BC-19	-123:32:02.0550	46:15:40.1670	29+40	Piller Rock
CR-BC-20	-123:29:16.2230	46:16:18.7428	32+05	Brooksfiel-Welch (L side)
CR-BC-21	-123:27:58.5393	46:16:05.1881	33+10	Skamokawa Bar (L side)
CR-BC-22	-123:26:17.2022	46:14:49.5667	33+10	ditto (L of Ctr., Chem)
CR-BC-23	-123:25:29.3459	46:12:33.2189	38+00	Puget Is. Bar
CR-BC-24	-123:25:38.0984	46:11:41.0153	39+00	Puget Is. Bar (R side, Chem)
CR-BC-25	-123:24:58.0377	46:10:15.4260	40+45	Wanna-Driscoll(L Ctr,Chem)
CR-BC-26	-123:23:14.5903	46:09:02.2613	42+40	ditto (L of Ctr., Chem)
CR-BC-27	-123:21:36.4559	46:08:41.7907	44+10	Wanna-Driscoll
CR-BC-28	-123:20:36.9378	46:08:32.5597	45+00	Wanna-Driscoll
CR-BC-29	-123:19:21.2834	46:08:32.0508	46+00	West Port Bar
CR-BC-30	-123:17:51.5459	46:08:37.8018	47+10	West port Bar
CR-BC-31	-123:16:52.1139	46:08:48.6908	48+00	West port Bar
CR-BC-32	-123:13:12.8288	46:10:14.6658	51+20	West port Bar
CR-BC-33	-123:09:35.6055	46:11:20.3455	54+30	Island Bar (L side)
CR-BC-34	-123:07:17.7356	46:11:07.9353	56+20	Stella-Fisher Bar (L side)
CR-BC-35	-123:06:15.6285	46:10:43.4611	57+20	ditto (R side, Chem)
CR-BC-36	-123:05:18.2519	46:10:09.7332	58+20	Stella-Fisher Bar
CR-BC-37	-123:11:29.7216	46:13:28.9081	59+10	Stella-Fisher Bar
CR-BC-38	-123:03:10.7658	46:09:15.3678	60+20	Walker Is. (L side)
CR-BC-39	-123:01:30.0908	46:08:26.9657	62+00	Walker Is.
CR-BC-40	-123:00:12.3010	46:07:58.3243	63+10	Slaughters Bar (Chem)
CR-BC-41	-122:59:29.9738	46:07:27.0209	64+00	Slaughters Bar Chem)

CR-BC-42	-122:58:38.1992	46:06:48.7298	65+00	Slaughters Bar
CR-BC-43	-122:57:52.6910	46:06:25.0230	65+40	Slaughters Bar
CR-BC-44	-122:57:20.4945	46:06:19.3331	66+10	R Turning Basin Lower
CR-BC-45	-122:56:30.9667	46:06:01.3646	66+50	R Turning Basin Upper
CR-BC-46	-122:56:09.8545	46:05:50.3446	67+15	L Dobelbower Bar (R side)
CR-BC-47	-122:53:00.0084	46:03:51.2050	70+45	U Dobelbower Bar
CR-BC-48	-122:52:46.5037	46:03:01.3898	71+45	U Dobelbower Bar
CR-BC-49	-122:52:17.2524	46:01:43.0832	73+25	U Dobelbower Bar (R side)
CR-BC-50	-122:51:07.9427	46:00:43.8057	74+50	Kalama (R of Ctr.)
CR-BC-51	-122:50:47.3695	45:59:53.3304	75+50	Kalama (R of Ctr.)
CR-BC-52	-122:50:21.3255	45:59:04.7564	76+50	@E8 on BiState (Chem)
CR-BC-53	-122:48:36.9406	45:57:26.6275	79+20	L Martin Is. Bar (L side)
CR-BC-54	-122:48:17.0262	45:56:23.2216	80+35	U Martin Is. Bar (L side)
CR-BC-55	-122:48:25.1414	45:55:07.9420	82+08	U Martin Is. Bar (Chem)
CR-BC-56	-122:48:25.0157	45:54:23.5578	83+00	U Martin Is. Bar (Chem)
CR-BC-57	-122:48:82.-----	45:54:32.------		@E9D on BiState (Chem)
CR-BC-58	-122:47:54.8348	45:53:04.4499	84+31	Jct w/ St. Helens Ch (Chem)
CR-BC-59	-122:47:25.0667	45:52:29.2106	85+20	St Helens Bar (L side, Chem)
CR-BC-60	-122:47:10.1016	45:52:07.1731	85+45	St Helens Bar (L side)
CR-BC-61	-122:47:04.2865	45:51:21.7615	86+40	ditto (L sideslope, Cem)
CR-BC-62	-122:47:15.7772	45:50:19.6795	88+00	Warrier Rock Bar
CR-BC-63	-122:47:35.6691	45:49:30.0103	89+00	Warrier Rock Bar (R side)
CR-BC-64	-122:47:33.9660	45:48:40.4233	90+00	Henrici Bar (R side)
CR-BC-65	-122:47:05.5824	45:47:53.7864	91+00	Henrici Bar
CR-BC-66	-122:46:28.2783	45:47:08.5875	92+00	Henrici Bar (L of Ctr.)
CR-BC-67	-122:45:51.3934	45:46:25.2233	93+00	Henrici Bar
CR-BC-68	-122:45:34.4431	45:45:36.7177	93+50	Henrici Bar (R of Ctr.)
CR-BC-69	-122:45:33.6004	45:44:42.5466	95+00	Henrici Bar
CR-BC-70	-122:45:36.7032	45:43:51.4174	96+00	Henrici Bar
CR-BC-71	-122:45:54.2874	45:43:00.7651	97+00	Willow Bar
CR-BC-72	-122:46:11.6581	45:42:10.0429	98+00	Willow Bar
CR-BC-73	-122:46:20.5107	45:41:00.6805	99+20	Morgan Bar (R of Ctr, Chem)
CR-BC-74	-122:46:27.7855	45:41:00.0435	99+20	Morgan Bar (Ctr. Ch, Chem)
CR-BC-75	-122:46:31.9109	45:40:59.6139	99+20	Morgan Bar (L side, Chem)
CR-BC-76	-122:46:07.9882	45:40:09.1738	100+20	Morgan Bar (R of Ctr)
CR-BC-77	-122:46:03.8366	45:39:47.0415	100+45	Morgan Bar (L side)
CR-BC-78	-122:45:35.0403	45:39:22.6433	101+25	Morgan Bar (R side)
CR-BC-79	-122:44:39.0406	45:38:50.7520	102+25	L Vancouver (R side)
CR-BC-80	-122:43:45.1358	45:38:37.8835	103+12	L Vancouver (R side, Chem)
CR-BC-81	-122:43:03.0185	45:38:27.3920	103+45	L Vancouver (R side)
CR-BC-82	-122:43:04.5671	45:38:25.2145	103+45	L Vancouver (Ctr. Channel)
CR-BC-83	-122:43:05.7394	45:38:23.1613	103+45	L Vancouver (L side)
CR-BC-84	-122:42:40.6247	45:38:19.6836	104+10	U Vancouver (R side, Chem Copper spill)
CR-BC-85	-122:42:16.1175	45:38:09.6405	104+10	U Vancouver (R side, Chem

				Copper spill)
CR-BC-86	-122:41:24.1493	45:37:38.6678	105+25	Downsteram RR Brdg(Chem)
CR-BC-87	-122:41:07.3576	45:37:29.9672	105+40	Upstream RR Brdg
CR-BC-88	-122:40:28.6568	45:37:16.7597	106+20	Downstream of I-205 Brdg (R of Ctr., Chem)
CR-BC-89	-122:40:32.7099	45:37:11.1850	106+20	Downstream of I-205 (L of Ctr)

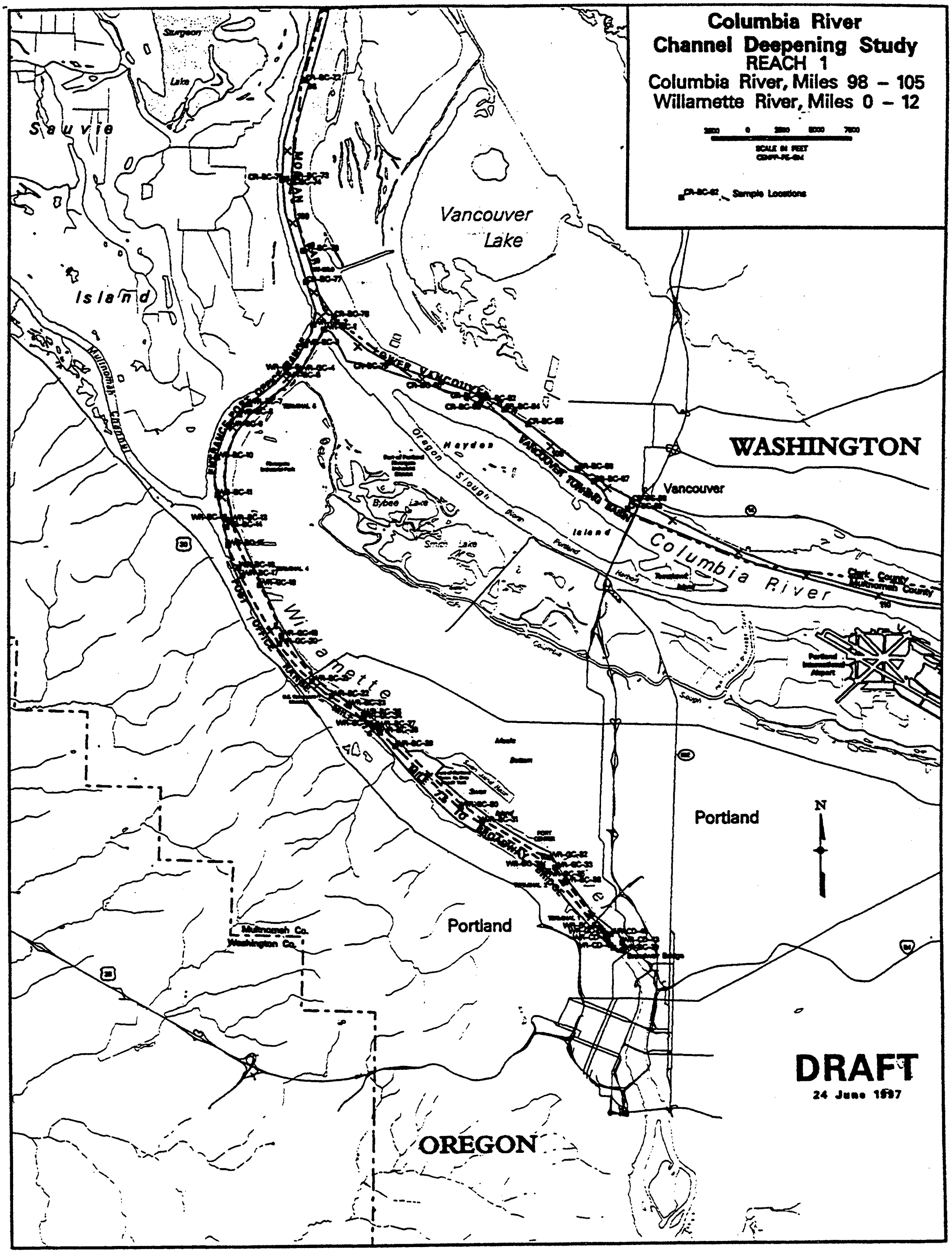
Columbia River Channel Deepening — 20-Jun-97

Willamette River Sampling Locations — US Army Corps of Engineers

Portland District

Sample	Longitude	Latitude	RM	Remarks
WR-BC-1	-122:45:44.3362	45:39:13.3370	0.1	Rt Mouth (Box Core)
WR-GC-2	-122:45:54.9805	45:39:16.5667	0.1	Lt Mouth (Gravity Core)
WR-BC-3	-122:46:02:3906	45:39:02.1708	0.4	Lt
WR-GC-5	-122:46:08.0703	45:38:44.7709	0.8	Rt D/S Term 5 (-4 w/-5)
WR-GC-4	-122:46:06.7203	45:38:43.8529	0.8	Lt D/S Term 5 (-5 w/-4)
WR-GC-6	-122:46:20.7350	45:38:42.8349	0.95	~ mid-channel
WR-BC-7	-122:46:57.3869	45:38:19.4082	1.6	"
WR-BC-8	-122:47:06.8303	45:38:12.1734	1.7	"
WR-BC-9	-122:47:16.6692	45:38:03.4129	2.05	"
WR-BC-10	-122:47:28.2057	45:37:41.3380	2.45	"
WR-BC-11	-122:47:26.2800	45:37:15.0665	2.9	"
WR-BC-12	-122:47:17.0763	45:36:57.6300	3.4	Rt D/S Term 4; Composite
WR-BC-13	-122:47:11.6621	45:36:57.1153	3.4	Lt of C/L; Composite-12,-14
WR-BC-14	-122:47:16.5328	45:36:52.2947	3.5	Lt of C/L; Composite-12,-14
WR-BC-15	-122:47:14.0216	45:36:39.3717	3.8	Rt of C/L
WR-BC-16	-122:47:02.7247	45:36:23.8457	4.1	~ C/L; Composite-16,-17
WR-BC-17	-122:46:58.8536	45:36:18.1072	4.4	~C/L ; Composite -16,-17
WR-GC-18	-122:46:41.0228	45:36:11.5496	5.1	Rt of C/L
WR-GC-19	-122:46:17.4757	45:35:35.8326	5.1	Rt of C/L
WR-GC-20	-122:46:19.2367	45:35:30.2858	5.15	L/t of C/L

Sample	Longitude	Latitude	RM	Remarks
WR-BC-21	-122:45:45.1441	45:35:04.2830	5.9	Lt D/S Moorings
WR-BC-22	-122:45:25.4092	45:34:53.8719	6.2	Lt D/S Moorings
WR-BC-23	-122:45:08.0541	45:34:47.6289	6.5	~ mid-channel
WR-GC-24	-122:44:52.1496	45:34:38.5182	6.7	Rt D/S RR Br
WR-BC-25	-122:44:52.4081	45:34:41.5870	6.7	Lt D/S RR Br
WR-BC-26	-122:44:43.0783	45:34:33.8529	6.9	Lt U/S RR Br; Comp-26,-28
WR-BC-27	-122:44:37.7302	45:34:33.4267	7.0	Rt U/S RR Br, Comp-26, -28
WR-BC-28	-122:44:35.0715	45:34:29.1617	7.1	~ mid-channel, Comp-26,-28
WR-BC-29	-122:44:19.6199	45:34:19.7144	7.5	~mid channel
WR-BC-30	-122:43:12.1918	45:33:37.2890	8.5	Swan Is
WR-BC-31	-122:42:50.2430	45:33:26.9055	8.9	Swan Is
WR-GC-32	-122:41:40.8248	45:33:02.8328	10.0	Rt D/S Turning Basin
WR-GC-33	-122:41:35.4903	45:32:55.6554	10.1	Rt U/S Turning Basin
WR-BC-34	-122:41:48.2905	45:32:56.4872	10.0	Lt D/S Turning Basin
WR-BC-35	-122:41:42.6042	45:32:52.9740	10.1	Lt U/s Turning Basin
WR-BC-36	-122:41:26.2867	45:32:45.0068	10.3	~mid-channel
WR-BC-37	-122:40:49.2764	45:32:13.2822	11.1	Lt of C/L
WR-GC-38	-122:40:43.1427	45:32:09.5219	11.2	C/L D/S Turning Basin
WR-BC-39	-122:40:25.7998	45:31:57.7696	11.65	C/L U/S Turning Basin
WR-CD-41	-122:40:40.4862	45:32:04.8735	11.35	Lt D/S Trn Bsn (Core Drill)
WR-CD-42	-122:40:35.1566	45:31:59.3912	11.5	Lt U/S Turning Basin
WR-CD-43	-122:40:26.1315	45:32:03.1942	11.55	Rt U/S Turning Basin
WR-CD-40	-122:40:37.7078	45:32:08.9439	11.3	Rt D/S Turning Basin



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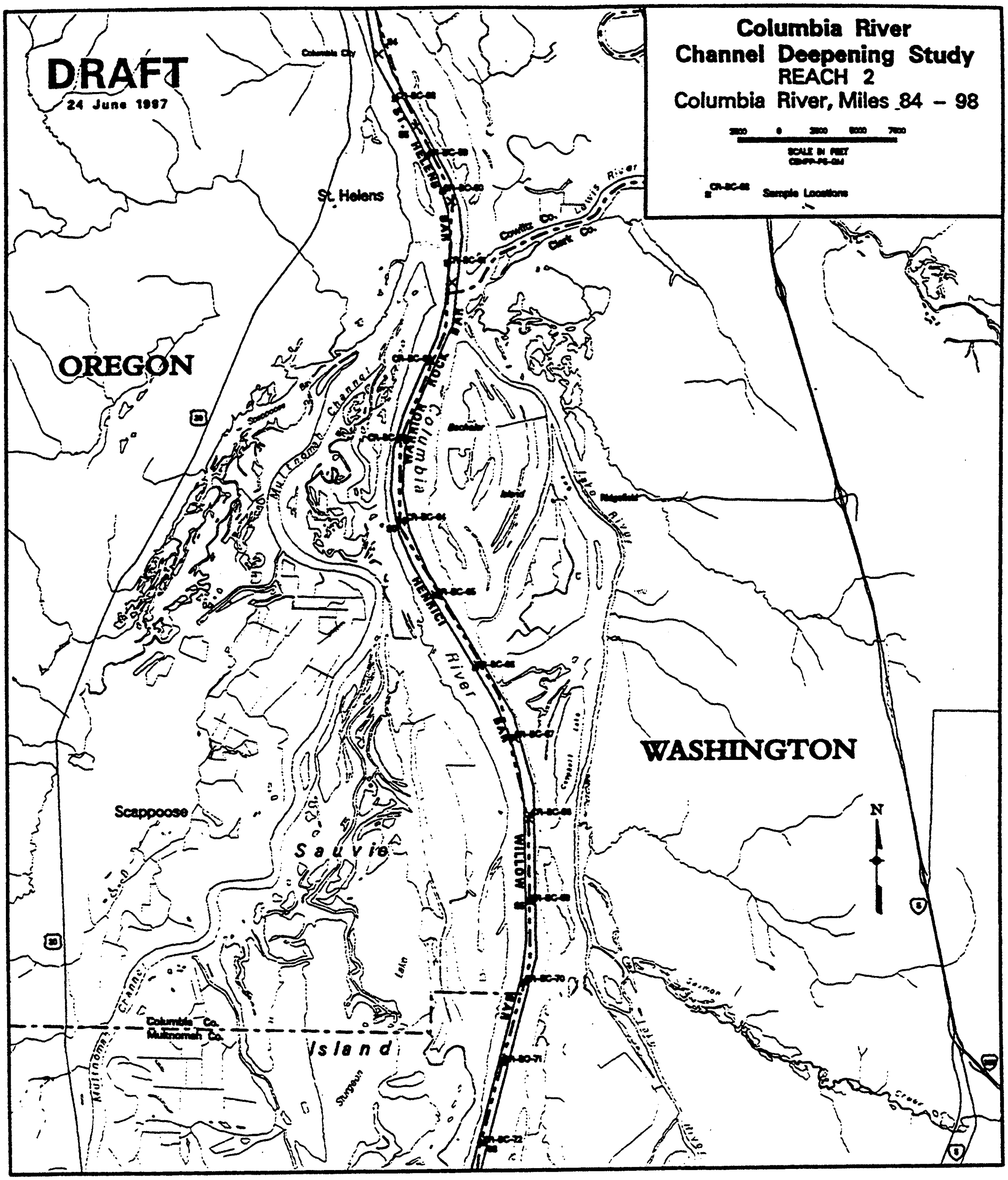

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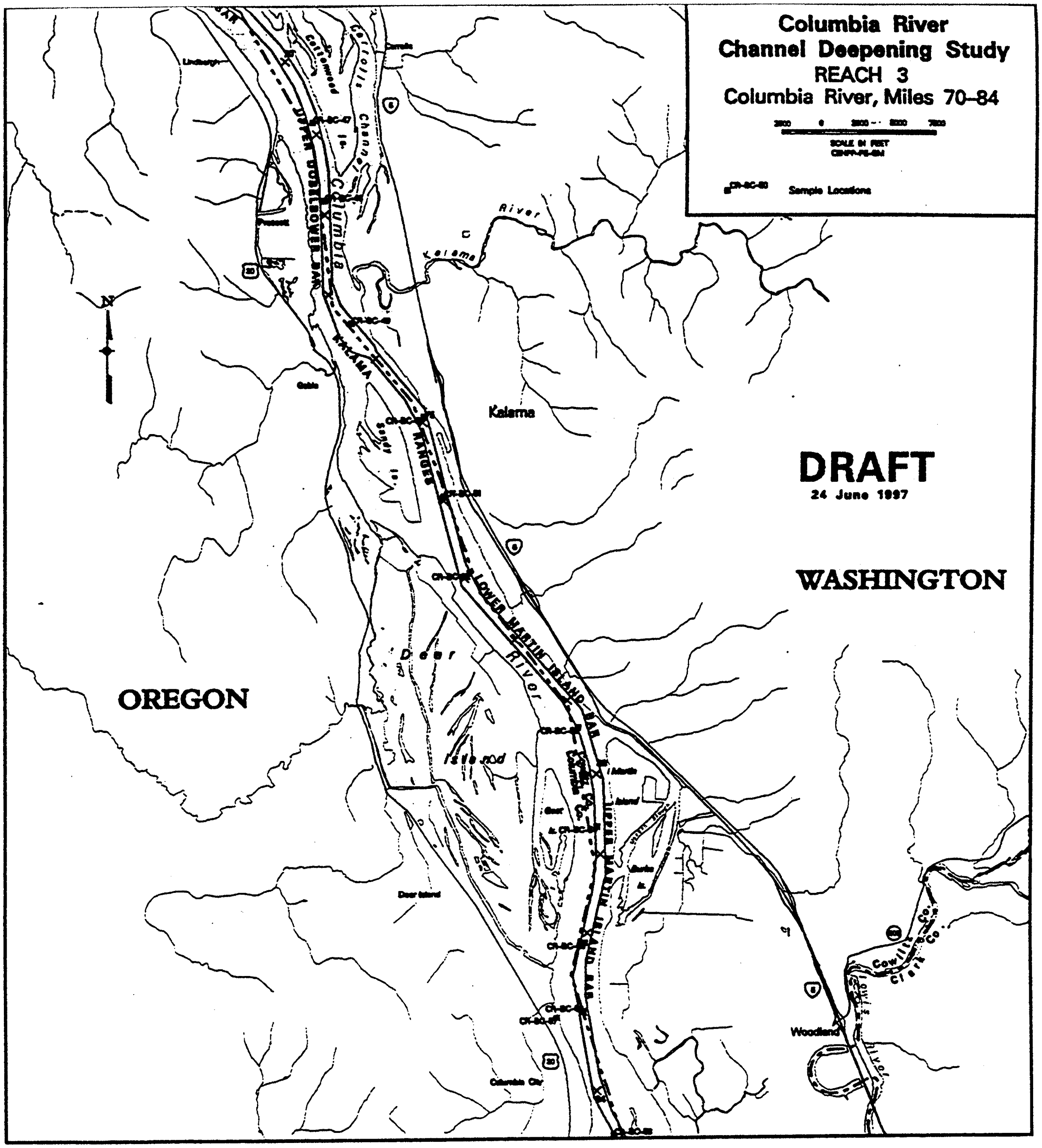

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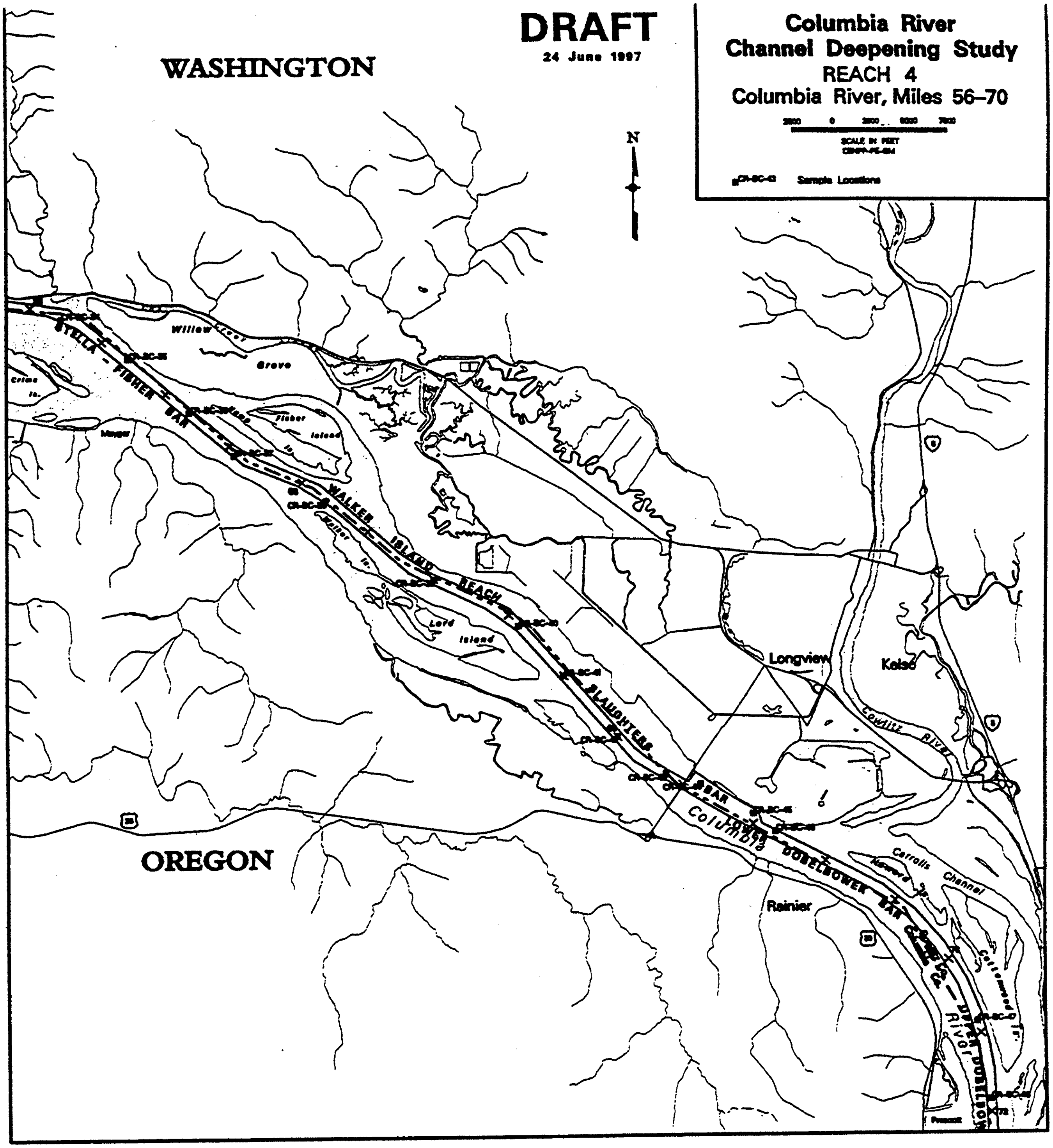

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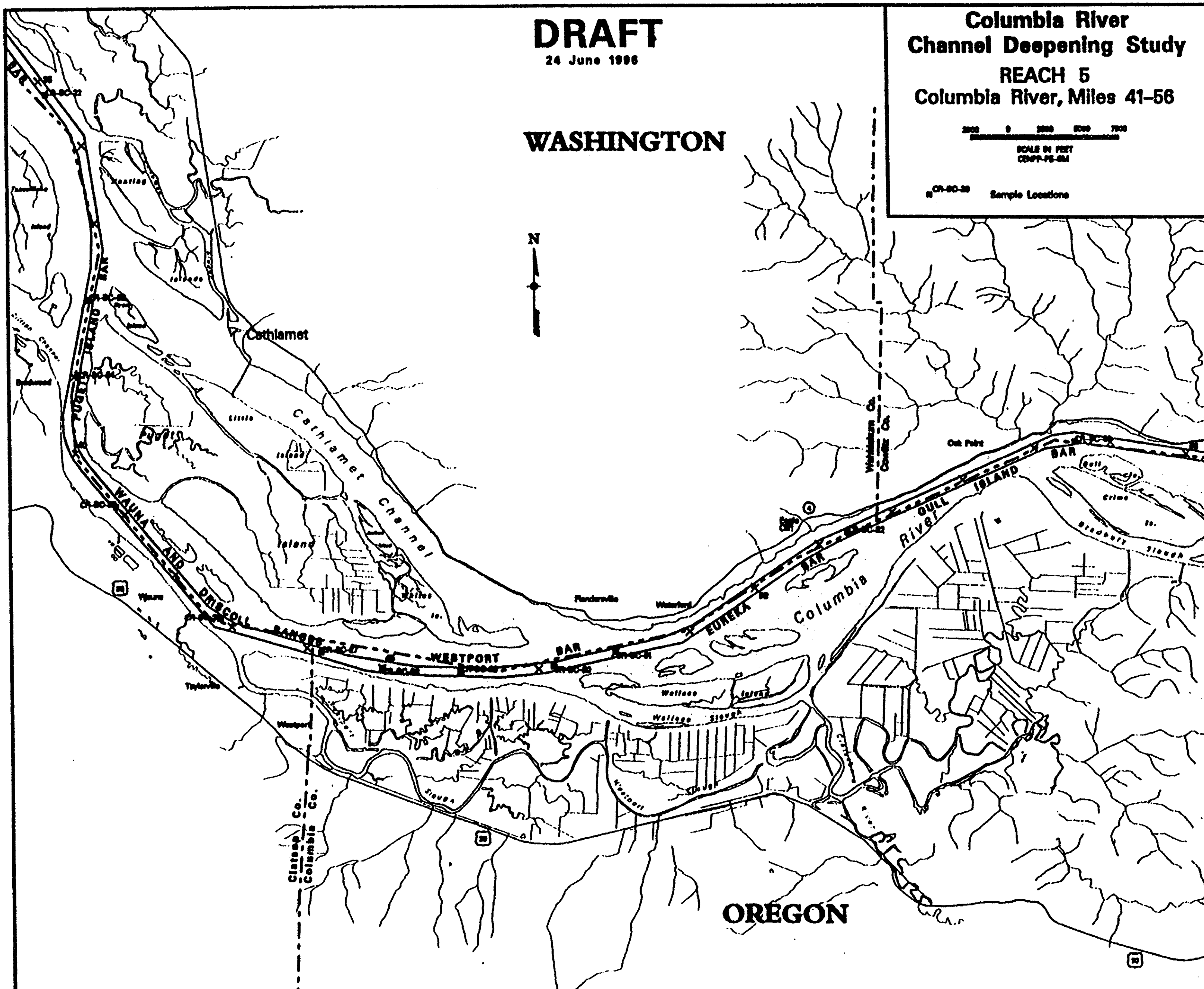

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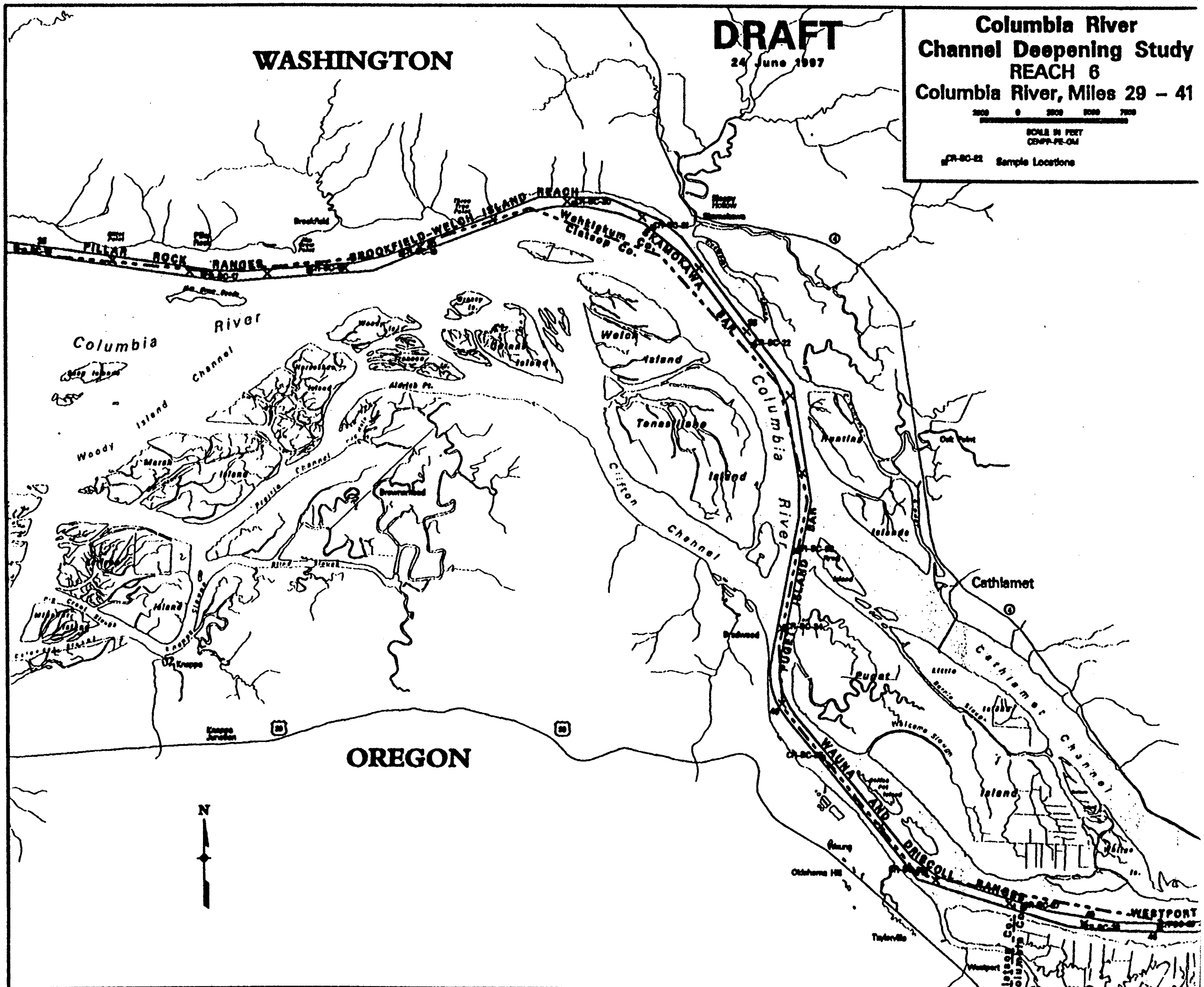

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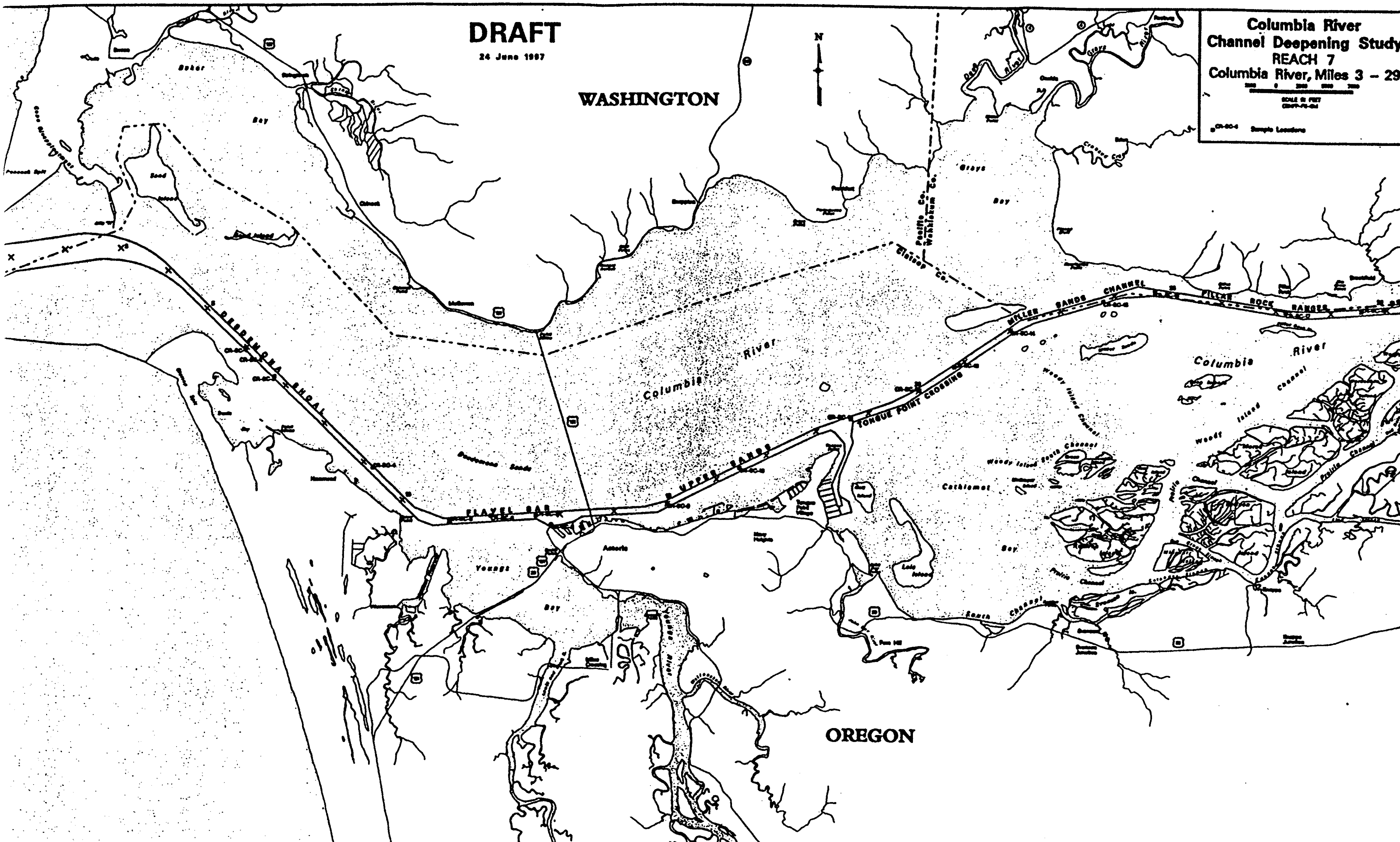

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APPENDIX C

HYDRAULICS AND SEDIMENTATION REPORT

(Appendix A from Nov. 1990 Columbia River
Channel Deepening Reconnaissance Report)

COLUMBIA RIVER

NAVIGATION CHANNEL DEEPENING STUDY

HYDRAULICS AND SEDIMENTATION REPORT

RECONNAISSANCE REPORT

APPENDIX A

Prepared By

U.S. Army Engineer District, Portland

November 1990

TABLE OF CONTENTS

COLUMBIA RIVER NAVIGATION CHANNEL DEEPENING STUDY
HYDRAULICS AND SEDIMENTATION REPORT

EXECUTIVE SUMMARY

This report presents the results of the hydraulic and sedimentation analyses done for the Columbia River navigation channel deepening study. The main emphasis of this report is a forecast of the future operation and maintenance (O&M) dredging for the proposed 42- and 45-ft navigation channels. Those channels follow the same alignment and use the same amount of advance maintenance dredging as the existing 40-ft channel. The 42-ft channel between RM 3 and RM 48 would initially add about 600,000 cy/yr to the existing O&M dredging. The 45-ft channel from RM 3 to RM 107 would initially increase O&M dredging by over 3.5 mcy/yr. Included in the new projects are improvements in dredged material disposal which will gradually reduce O&M requirements for the project. The O&M quantities return to current levels in about 20 years. The improved disposal practices will require some changes in the type of dredge used to maintain certain bars, but relies mainly on the same equipment currently used in the Columbia River.

The hydraulic impacts of the 42- and 45-ft channels are expected to be minor. Due to the wide variation in existing channel hydraulics, the changes in velocities and water surface elevations will generally fall within the normal range of river conditions. Deepening the channel will result in increased riverbed erosion near the dredging locations, leading to the increase in O&M dredging. As sediment is removed from the river by dredging there will be an increase in the average river depth and increased shoreline erosion. Shoreline erosion will mainly occur along the sandy beaches created by past disposal operations.

INTRODUCTION

Purpose.

This report documents the hydraulic and sedimentation analyses performed for the Columbia River Navigation Channel Deepening Study. The emphases of this work has been on forecasting future operation and maintenance (O&M) dredging, and evaluating the potential hydraulic and sedimentation impacts. The alternatives considered were a 42-ft channel between river miles (RM) 3 and 48, and a 45-ft channel from RM 3 to RM 107. To provide a measure of the expected changes with a new project, descriptions are given of existing river conditions, current O&M practices and potential improved O&M practices for the 40-ft channel.

Methods.

The methods used in this study are in accordance with EC 1110-2-265, Engineering and Design for Civil Works Projects, dated 1 September 1989 and EM 1110-2-1613, Hydraulic Design of Deep-Draft Navigation Projects, dated 8 April 1983. The hydraulic and sedimentation analyses relied on historic dredging and bathymetric data dating back to the 1890's and on recent studies of O&M practices and river behavior between RM's 3 and 53. Knowledge of dredging and river processes gained during the Lower Columbia River Maintenance Improvement Review (MIR) (USACE Portland, 1988) and the Long-Term Management Strategy for Dredged Material Disposal in the Columbia River Estuary (LTMS) (USACE Portland, 1990) was particularly useful and was extrapolated to the remainder of the study area.

Limitations.

The major limitations of this study are related to the intent of the reconnaissance phase of the planning process to only determine if there is a Federal interest in a proposed project. Only two alternatives (42-ft between RM's 3 and 48, and 45-ft between RM's 3 and 107) were evaluated in the study and no attempt was made to optimize those alternatives. For purposes of this analysis, the "with-project" channel alignment, width, and O&M dredging practices were kept the same as those of the current 40-ft channel. The safety and navigability of the proposed alternatives for ships larger than those of the current Columbia River fleet could not be addressed because a "design vessel" was not identified.

A decision was made at the beginning of the study that dredged material disposal would be upland or ocean where possible, and that in-water and shoreline disposal would only be used where favorable conditions existed. The selected disposal plan differs from current practices, but is expected to be more economical and simplified the O&M dredging analysis.

Construction of new river control structures, suitability of the Columbia River entrance channel for deeper draft ships, and possible changes in advance maintenance dredging (AMD) practices were not included in this reconnaissance study. While control structures have the potential to significantly reduce long-term O&M dredging requirements, there was not sufficient time or money to evaluate them during the reconnaissance phase. The entrance channel may require deepening to transit deeper ships without delays, but since it is a separate project from the river channel it was not included in this study. AMD practices effect both the initial construction volume and the long-term O&M dredging, but again were not evaluated because of the time and funding limitations.

DESCRIPTION OF STUDY AREA

Morphology.

The Columbia River deep-draft navigation channel extends from the mouth to the Portland, Oregon/Vancouver, Washington area, about River Mile (RM) 107. The area covered by this study is that portion of the Columbia River channel between RM's 3 and 107 and the Willamette River from RM 0 to RM 11. The Columbia River reach was divided into an estuarine reach downstream of RM 25 and riverine reach upstream of that point. The general planform of the study area is shown in Figure 1.

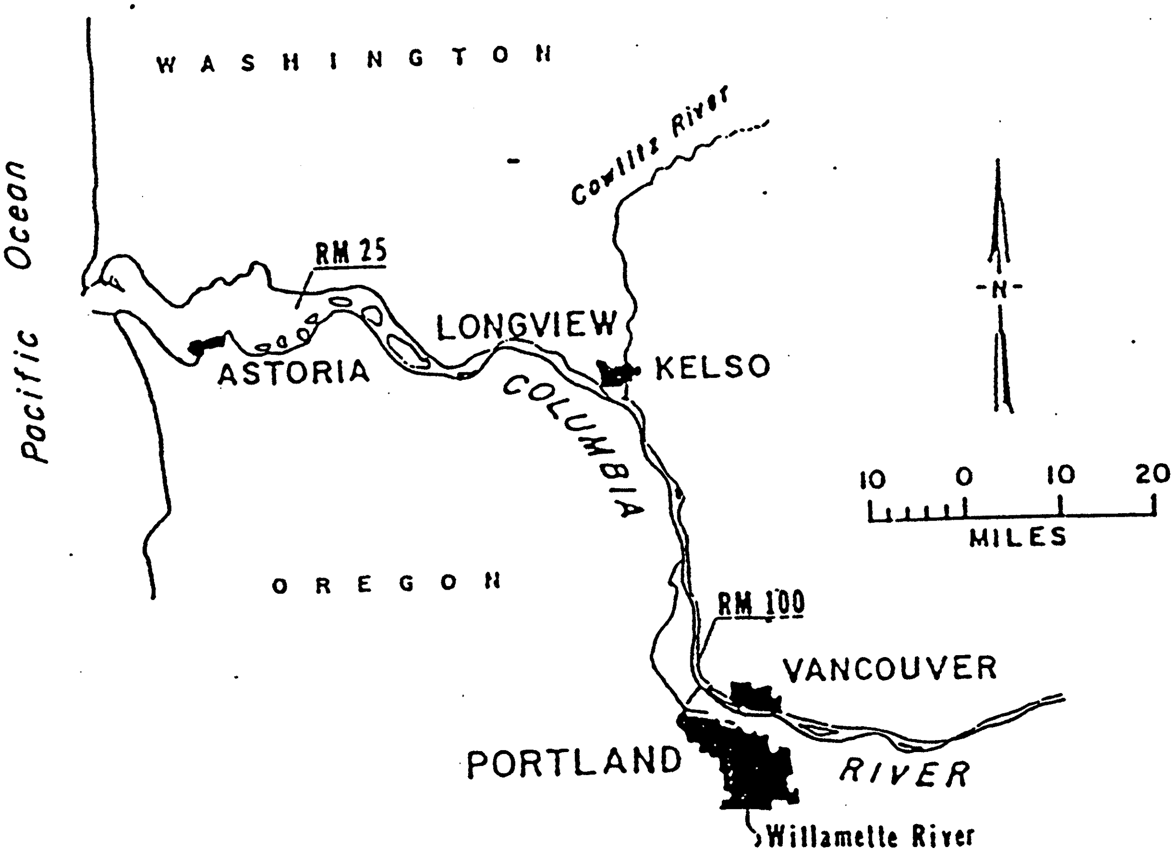

Figure 1. Study Area Map.

Estuarine Reach. The Columbia River estuary is 4-5 miles wide and extends upstream to around RM 25. It contains two main channels, the North and South channels. The South Channel is an extension of the main river channel upstream of the estuary and carries most of the upland river discharge. The navigation channel follows the South Channel through the estuary. The North Channel extends upstream to about RM 20, near Gray's Bay. These two deep channels are separated by wide, shallow inter-tidal and sub-tidal flats.

Riverine Reach. Upstream of RM 25, the main Columbia River channel generally varies from 1700 ft to 3000 ft wide, with minor bifurcations. Portions of the river have been constricted by pile dikes and sand fills in efforts to improve navigation channel maintenance. The amount of constriction varies from a few hundred feet to several thousand feet. The river bends tend to have very long radii, typically over 15,000 ft. Sharper bends only occur where basalt cliffs control the river's alignment, such as near RM's 32, 40, and 54. The bed of the main channel is composed of deep deposits of mostly fine and medium sand (0.125-0.50 mm). Silt and clay make up less than 5 percent of the main channel's bed material. The natural riverbanks consist of basalt or erosion resistant silt and clay deposits. These overbank silt-clay deposits range from 20 ft to 150 ft thick and overlay much deeper sand deposits. Sandy beaches occur only where dredged material has been placed along the shore. There has been little change in the river's location in the last 6,000 years (USACE, 1986).

Navigation development has had an impact on main channel depths as well on widths. Current thalweg depths are generally near 50 ft throughout most of the study area. This is only slightly deeper than prior to navigation development when much of the main river channel had natural thalweg depths in the 35 ft to 45 ft range. However, the controlling depth (minimum depth available anywhere along the navigation channel) has increased from about 12 ft prior to development, to 40 ft for the present channel. Typically, depths across the entire channel have also increased in reaches with large hydraulic control structures or high dredging rates. Channel areas with depths of over 50 ft occur mainly on the outside of bends and around rock outcroppings.

Navigation Channel Development.

The Columbia River navigation project was originally authorized in 1878 with a 20-ft minimum depth. The navigation depth was increased to 25-ft in 1899. In 1912, the project authorization was changed to 30-ft deep by 300-ft wide and construction was completed in 1920. Between 1930 and 1935, the navigation channel was again enlarged, this time to 35-ft deep by 500-ft wide. The current 40-ft deep by 600-ft wide channel was authorized in 1962 and completed in 1976. Beginning with the 20-ft channel in the 1880's, the design depth has been achieved and maintained through a combination of dredging and hydraulic control works.

Dredging has been required to construct and maintain each stage of channel development. The annual dredging volumes to construct and maintain the navigation channel since 1906 are shown in Figure 2. Prior to 1912 and construction of the 30-ft channel, dredging was limited to a few very shallow reaches of the river, where the natural controlling depths were in the 12-15 ft range. From 1912 to 1935, dredging became necessary along most of the channel and the annual volumes reflect a combination of almost continuous channel development and O&M activities. During this time, the channel was deepened twice (at some locations new depths were constructed in one operation and at other locations it was done in stages), widened to 500 ft, much of the channel was realigned, and many hydraulic control structures were built. Dredging was especially high between 1930 and 1935, during construction of the 35-ft by 500-ft channel. The period from 1936 to 1957 was one of primarily O&M dredging, except for some continuing channel alignment adjustments that added to the dredging requirements. During the 1936 to 1957 period, dredging averaged 6.7 mcy/yr. By 1958, the channel alignment had generally stabilized, but, O&M dredging was augmented to increase the depth of advance maintenance dredging (AMD) from 2 ft to 5 ft to allow the channel to shoal for a year and still provide full project dimensions (USACE Portland, 1961). The current 40-ft by 600-ft channel was constructed in stages between 1964 and 1975. Since 1976, O&M dredging has averaged approximately 6.5 mcy/yr, after making adjustments for emergency dredging related to the eruption of Mount St. Helens in 1980.

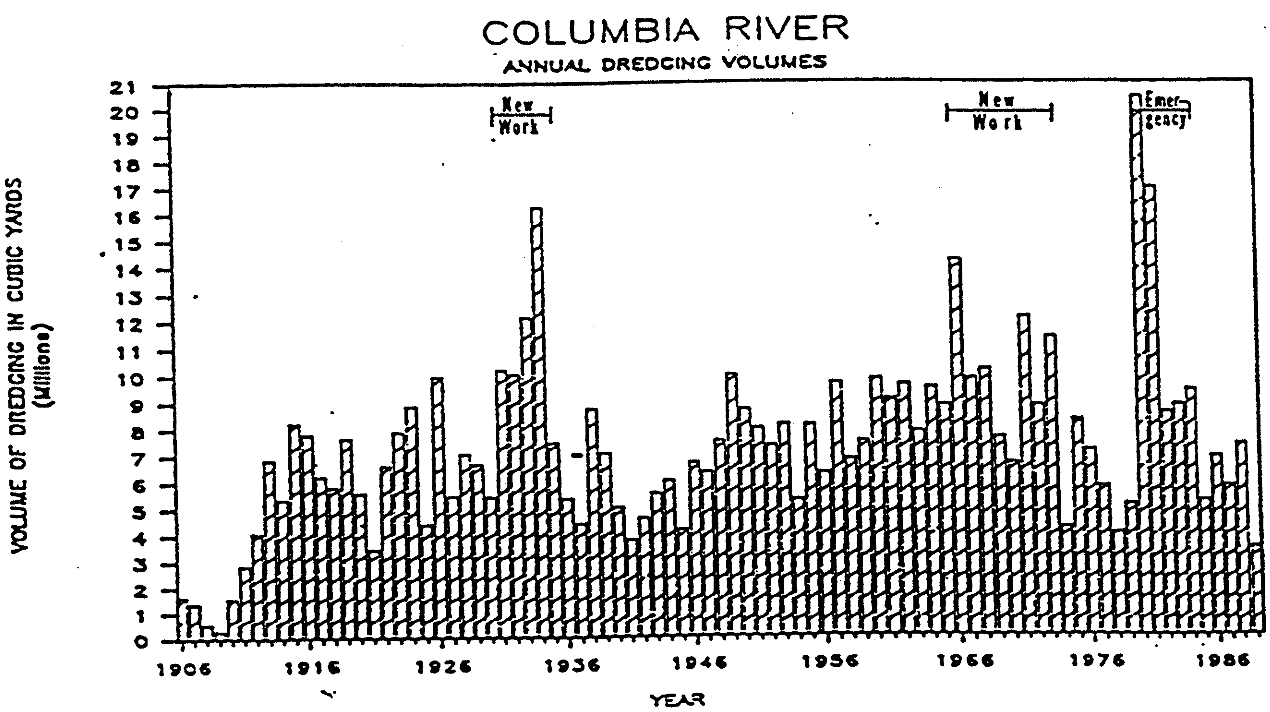

Figure 2. Historic Columbia River Dredging Volumes.

Pile dikes are a common hydraulic control measure in the river. They have been used to improve channel alignment for navigation, reduce cross-sectional area, restrict flow in back-channels, and provide bank protection. The Corps initiated pile dike construction in 1885, but the bulk of the pile dike system was built between 1917 and 1939. The last significant additions to the pile dikes system were built during construction of the 40-ft channel in the 1960's to further constrict flow and reduce erosion at dredged material disposal sites. The Corps currently maintains a total of 236 pile dikes within the study area.

Sand fills, constructed with dredged material, have also been used extensively to reduce channel cross-section and control channel alignment. Most fill has been placed along the shoreline to constrict flow. Upstream of RM 20, nearly half the shoreline along the main channel is composed of dredged material fill. Dredged material has also been used to create several islands to control channel alignment, such as Coffeepot, Lord, Sandy, Goat, and Sand islands. Pile dike fields protect most of these dredged material fill sites from erosion.

A long period of riverbed adjustment has followed each step in navigation channel development. The amount of dredging required to maintain the navigation channel during these adjustment periods has depended on the magnitude of the disturbance to the pre-existing riverbed. The development actions have included channel deepening, constrictions, realignments, and fills. The channel deepenings may be viewed as low intensity disturbances that impacted large areas and significantly increase O&M dredging. Many of the constrictions, realignments, and fills have caused high intensity, local area disturbances that also caused significant increases in O&M dredging. Because of the frequency and variation of channel development activities, there is no simple correlation between channel depth and O&M dredging requirements. Future O&M dredging will depend on the magnitude of the overall disturbance to the riverbed.

The current navigation channel is maintained to minimum dimensions of 40-ft deep and 600-ft wide. It generally follows the river's thalweg and most of the channel is deeper than the required 40 ft. Shoals tend to form in reaches of the channel where the depths prior to construction were less than 40 ft. Hopper and pipeline dredges annually remove about 6.5 mcy of sand from the shoals in the navigation channel. Material from hopper dredges is disposed of in deep water outside the navigation channel. The most common practices for pipeline dredges are upland and shoreline disposal. Occasionally, a pipeline will end-dump material in-water alongside the channel.

Hydrology.

The Columbia River drains 259,000 sq mi, originating in Canada's Columbia Lake and flowing 1,214 mi to the Pacific Ocean. The average annual discharge at the mouth is over 210,000 cfs. Flow from the upper Columbia River is dominated by snowmelt, causing low winter flows and spring freshets. Heavy winter rainfall in the lower basin can cause winter freshets to occur in the study area. Reservoirs upstream of the study area, store water during the spring snowmelt. After completion of the large Canadian storage reservoirs in the early 1970's, the 2-yr flood peak at The Dalles, OR., was reduced from 580,000 cfs under natural conditions to 360,000 cfs with regulation (USACE North Pacific, 1987). Flows in the study area would be slightly higher due to local inflows. Low flows, typically in the 100,000 cfs range, occur in September and October, after the snowmelt runoff but before the winter rains. Stored water is released during the fall low flow period to increase hydro-electric power generation.

Hydraulics.

Ocean tides produce complex, unsteady flow conditions in the lower 140 miles of the Columbia River. The mean tide range is nearly 8 ft at the mouth and about 2.5 ft at Vancouver. Because of this tide range, instantaneous discharges can range from negative values (upstream flow) during the flood tide, to twice the mean daily value at peak ebb flow. The tidal effects are much greater during low river flows than during high flows.

The estuary has two deep-water channels, one on the north side and one on the south side. The North Channel extends upstream to Grays Bay (about RM 20), but is only connected to the main river channel by shallow cross estuary channels and tidal flats. The North Channel is, in general, a slightly flood dominant channel. The South Channel is the main river and navigation channel. The South Channel is heavily ebb dominant, giving the estuary a net clockwise circulation pattern.

Between RM's 20 and 30, the main channel shifts to the north side and numerous shallow channels flow through Cathlamet Bay on the south. Upstream of RM 30, the river has a single main channel, with occasional side channels around islands. In the main channel, typical peak ebb velocities are in the 3 fps range, with freshet velocities over 6 fps. During extreme low flows, flow reversals can occur as far upstream as RM 90.

SEDIMENT BUDGET

A sediment budget for the Columbia River was used to identify the historic source of shoal material in the navigation channel. Suspended and bedload transport were analyzed, as well as pre- and post-regulation sediment transport.

Suspended Sediment.

The suspended sediment concentrations in the Columbia River are quite low. Measurements taken during the spring freshet in 1922, before any large dams were built, found an average suspended sediment concentration of 130 ppm downstream of the Willamette River (Hickson, 1961). Measurements taken in 1959 and 1960 (USACE Portland, 1961) and in the 1980's (USGS, 1980-1986) found similar concentrations. Based on observed concentrations and appropriate flow-durations curves, the Corps estimated that the average annual suspended sediment yield at Vancouver, WA., has been reduced from 12 mcy/yr pre-regulation to only 2 mcy/yr post-regulation (USACE Portland, 1986).

Not all the suspended sediment in the Columbia River contributes to the shoaling problems. A review of the USGS sediment data indicates 80-90 percent of the suspended sediment is silt or clay, material not found in significant quantities in the bed of the navigation channel. Sand, which makes up about 95 percent of the bed material, is generally less than 15% of the suspended load, and increases to over 30% only when the discharge exceeds 400,000 cfs. This indicates the current average suspended bed material transport into the study area is between 0.2 and 0.6 mcy/yr.

Bedload.

No attempt has been made to directly measure the bedload transport of the Columbia River. However, bedload estimates have been made using two independent methods. An empirical equation developed by the USGS was used to estimate unmeasured load for pre- and post-regulation conditions. That equation is based on the modified Einstein equation and relates unmeasured load to river discharge (USACE Portland, 1986). Applying this equation to the pre- and post-regulation flow-duration curves resulted in bedload estimates of 1.5 mcy/yr pre-regulation and 0.2 mcy/yr post-regulation.

The second estimate was made by equating bedload transport to the movement of the sand waves present on the bed. Sequential surveys were made of two sets of sand waves, one during high flow conditions and the second during average discharge conditions. The analyses of those surveys and flow conditions resulted in bedload estimates ranging from 0.1 mcy/yr to 0.4 mcy/yr. The analysis also found that large sand waves only moved several hundred feet a year.

Shoal Material Sources.

Comparing the average O&M dredging volume of 6.5 mcy/yr to an average total bed material transport rate of 1.0 mcy/yr indicates less material is being transport into the study area than is dredged from the navigation channel. Therefore, the main source of shoal material must be within the study area. Bathymetric surveys (USACE Portland, 1800's-1990) indicate that there has been significant bed degradation in areas adjacent to the most commonly dredged reaches. Experience has also shown that beach erosion occurs at most shoreline disposal sites. These sandy shorelines are much more easily eroded than the natural silt/clay banks. Given the small amount of bed material inflow and the stability of the natural banks, the most likely sources of shoal material are riverbed degradation outside of the navigation channel and erosion from shoreline dredge material disposal sites. Where dredged material has been removed from the active sediment transport system (placed in stable disposal sites), there has been a gradual lowering of riverbed elevations and a corresponding reduction in shoaling.

Shoaling Processes.

The vast majority of the Columbia River navigation channel shoaling is the direct result of bedload transport. The two dominant shoal forms are large sand waves and cutline shoals. Sand waves are present throughout the river channel and cause shoals across the channel where wave crests rise above the channel design depth of -40 ft Columbia River Datum (CRD). Cutline shoals are much larger and run parallel to the channel. Cutline shoals develop at the same locations year after year.

Sand Wave Shoals. Sand waves have long been recognized as a shoaling problem in the Columbia River. Hickson (1930) noted 8- to 10-ft sand waves forming ridges across the 30-ft deep channel. Sand waves create similar shoals in today's 40-ft channel. **Figure 3** shows the variation in size and shape that is typical of this type of shoaling. The volume of an individual sand wave shoal is small, generally less than 30,000 cy, but they are numerous enough to represent a significant amount of the annual O&M dredging.

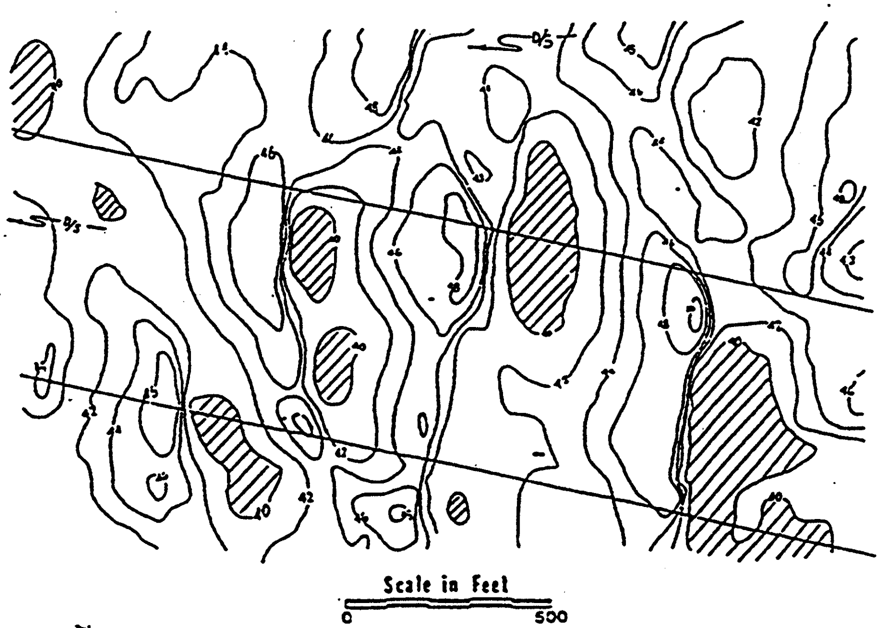

Figure 3. Sand Wave Shoal Pattern.

Sand wave shoals do not appear at the same location each year because of the time required for the waves to form and grow. The 5-ft of advance maintenance dredging utilized in the Columbia River, means the sand waves must grow to 8-to 10-ft high before they become shoals. The main source of material for sand waves is the bed of the navigation channel. Dredging leaves a flat channel bottom on which the waves form. The wave troughs are scoured from below the dredged surface, with material from the trough then forming the wave crest. Because the maximum wave height seldom exceeds 12 ft, sand waves shoals do not occur where the channel bottom is much deeper than 45-ft CRD.

Cutline Shoals. Cutline shoals form along the navigation channel dredging cutline, parallel to flow, and can extend several thousand feet along the channel. Cutline shoals begin forming at the edge of the dredged cut and grow out toward the center of the navigation channel. In the Columbia River, these shoals occur on the inside of long bends and on straight river reaches. They are especially severe in areas of the river that were less than 40-ft deep prior to construction of the existing channel. Cutline shoals are much larger than sand wave shoals, the 12 largest cutline shoals account for nearly half of the annual 6.5 mcy of O&M dredging. Grishanin and Lavygin (1987) concluded that this mechanism is also the main cause of shoaling of dredge cuts in Russian rivers with sandy beds.

The primary cause of cutline shoals is gravity pulling bedload down the side-slopes and into the navigation channel. As river currents move bedload over a bed with a transverse slope, gravity will give the sediment a transverse velocity component independent of the water (Fredsoe, 1978). The steeper the transverse slope, the greater the deflective force on the bedload. Bedload on or near the 1V:3H cutline would therefore be deflected sharply toward the navigation channel. The bedload within the dredged channel would have a very slight, or no, transverse velocity component because of the flat surface of the cut. Along the cutline there would be a convergence of bedload moving downstream in the navigation channel and transversely on the side-slope, resulting in the formation of a shoal. Figure 4 shows the theoretical bedload movement caused by a combination of hydraulic and gravitational forces. This process causes the side-slopes to erode until an equilibrium transverse slope is reached for the deeper channel.
The erosion and resulting shoaling decline as the side-slopes move toward equilibrium conditions.

CURRENT 40-FT CHANNEL MAINTENANCE

The Columbia River navigation channel is currently maintained to minimum dimensions of 40-ft deep by 600-ft wide, by a combination of dredging and river control structures. O&M dredging averages approximately 6.5 mcy/yr. Figure 5 shows the current average annual O&M dredging volumes by bar. This dredging is done by hopper dredges with in-water disposal and pipeline dredges using shoreline or upland disposal.

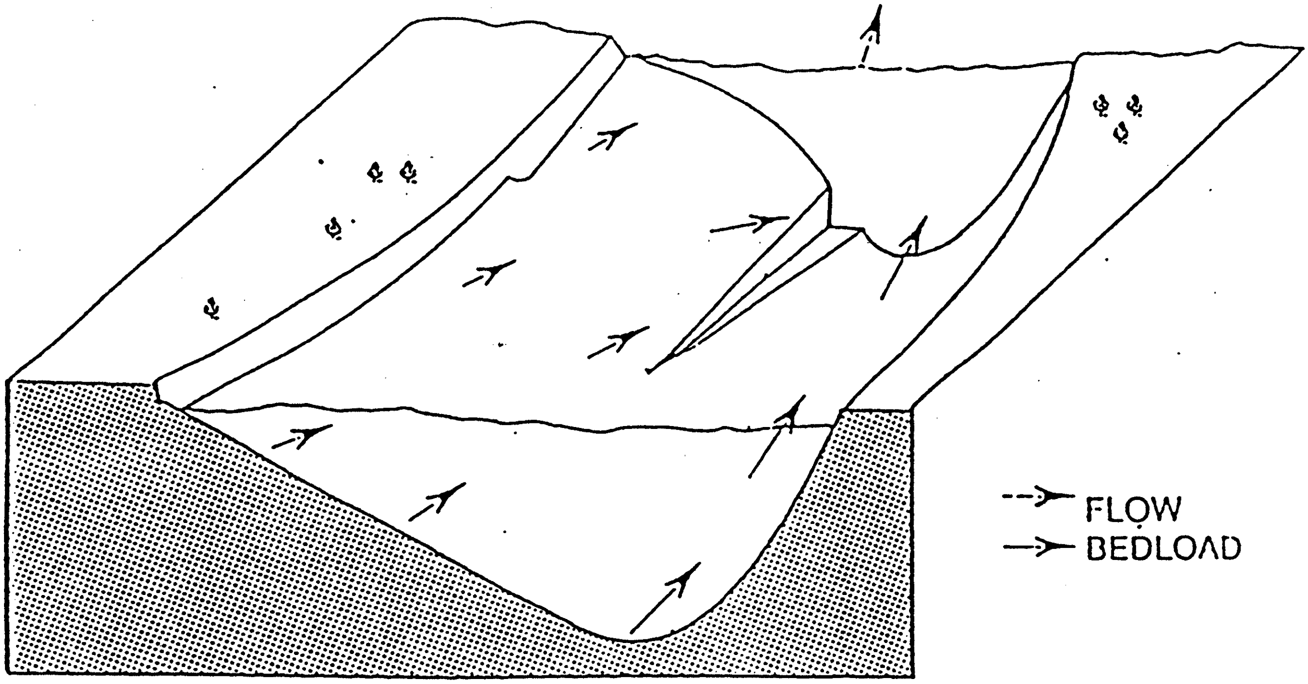

Figure 4. Bedload Transport Paths.

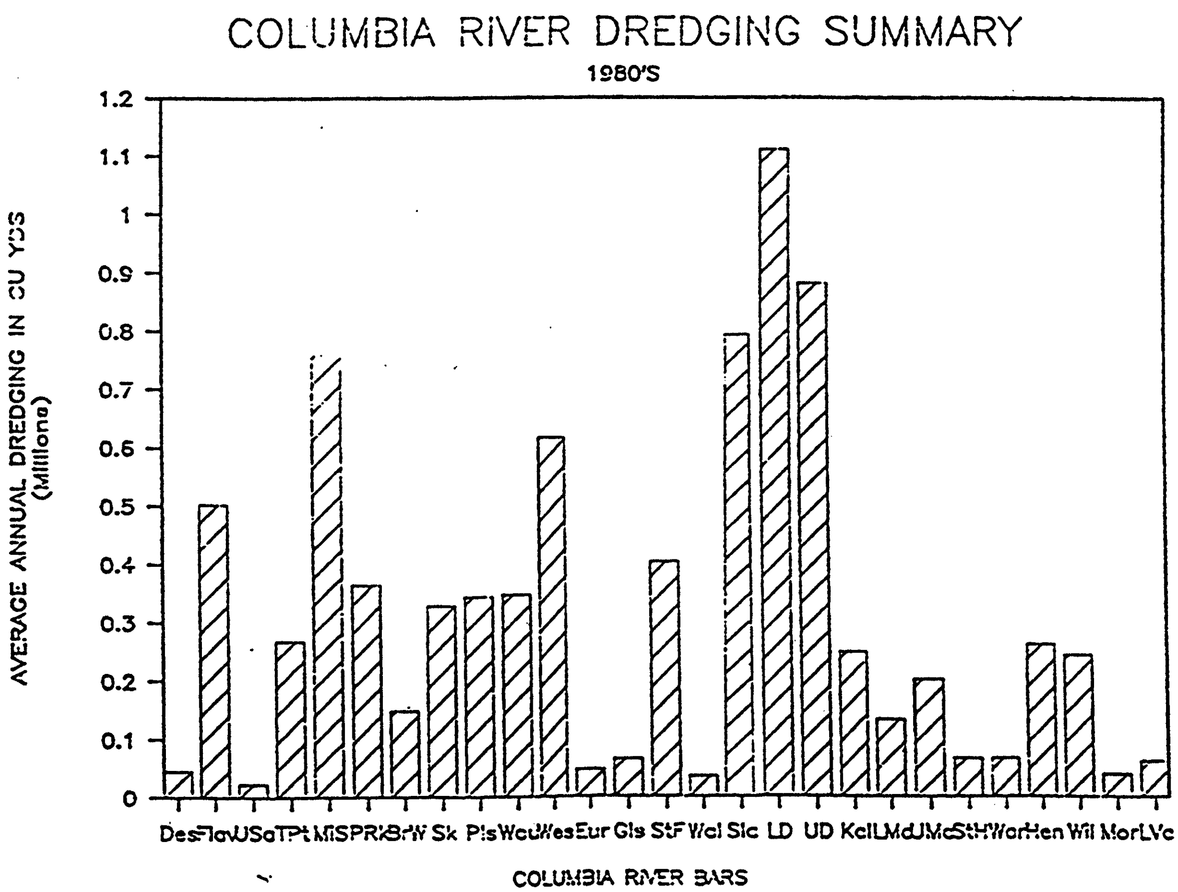

Figure 5. Average Annual O&M Dredging during the 1980's, including Mount St Helens Restoration Work.

Dredging and Disposal Practices.

O&M dredging is generally done by hopper and pipeline dredges. The type of dredge used on a shoal depends on several factors, including dredge availability, size and location of the shoal, and disposal options available. A sand wave skimmer was recently tested in the Columbia River, but did not proved to be an economical maintenance option. If operational improvements are made, the skimmer could be tried again. Dredging beyond the minimum required dimensions is done to increase channel availability and reduce dredging frequency at a bar.

Hopper Dredging. Hopper dredges currently do about 3 mcy/yr of O&M dredging in the Columbia River. Most of this dredging is done by the Corps' hopper dredge "Essayons". Hopper dredges provide flexibility for dredging operations because they can operate anywhere on the river and can be rapidly deployed to problem shoals. Hopper dredges are most often used on small volume shoals, such as sand wave areas, and on larger shoals in the estuary. The "Essayons" may spend several weeks in the early spring and in the fall dredging small shoals in the Columbia River upstream of RM 25. During the summer, the estuary work is done as backup work for the dredging at the mouth of the river. When the entrance becomes too rough or foggy for hopper dredges to work, they will move to one of the estuary shoals to dredge. The main restriction on the use of hopper dredges is the limited availability of in-water disposal sites with enough deep water to allow disposed without creating a new shoal. Flowlane disposal (material is spread in deep-water areas adjacent to the navigation channel) is used for hopper operations upstream of RM 25. In the estuary, hopper disposal is done at a large disposal site (Area D) located away from the navigation channel near RM 6 and a in-water sump near RM 21.

Pipeline Dredging. Pipeline dredges are used for the large cutline shoals and areas with multiple sand wave shoals. About 3.5 mcy/yr are dredged by pipeline dredges, nearly all by the Port of Portland's dredge "Oregon". Pipeline dredging is done during the summer. Typically, the "Oregon" will be scheduled to start at one end of the navigation channel and work its way to the other end. This minimizes the amount of time spent moving the dredge and related equipment. The most common pipeline disposal practice for O&M work is to place material along the shoreline near the dredging site. Many of these shoreline sites are actively eroding and contributing sand back to the navigation channel. Upland disposal is a more effective disposal method, but very few upland sites are available for O&M operations. Occasionally, pipeline disposal will be done in-water adjacent to the navigation channel, but this is not a preferred practice.

Advance Maintenance Dredging. During O&M dredging operations, advance maintenance dredging (AMD) is done beyond the 40-ft by 600-ft dimensions of the navigation channel. The purposes of AMD are to provide year-round channel availability and to allow an annual dredging cycle. AMD of up to 5 ft was authorized for the 40-ft channel. The amount of AMD varies with the type of shoal and dredge. Pipeline dredges are better suited for large cuts than hopper dredges. Pipeline dredges will normally do the full 5 ft of AMD, but hoppers may do from 2 ft to 5 ft of AMD. A review of AMD practices during the Maintenance Improvement Review (USACE, Portland, 1988) found 5 ft AMD to be sufficient to minimize sand wave shoaling problems, but not well suited for the cutline shoals. Based on the recommendations from that review, AMD recently has been done outside the channel boundaries to intercept material moving toward the large cutline shoals.

River Control Structures.

River control structures aid in channel maintenance by controlling flow alignment, reducing erosion, and providing areas for disposal. The current network of control structures provides a smooth channel alignment that reduces erosion and aids navigation. The pile dike fields protect many millions of cubic yards of disposal material from erosion. However, the system has reached, and often exceeded, its limits for disposal site protection. Many shoreline sites have been filled beyond the limits of erosion protection provided by the dike fields and are actively eroding. Recent investigations (USACE, Portland, 1988 & 1990) have recommended construction of additional pile dikes to protect disposal sites at Miller Sands, Pillar Rock, Puget Island, and Westport bars.

BASE CONDITIONS

Base conditions are the 40-ft channel maintenance practices to which future O&M dredging are compared to arrive at the incremental volume of deeper channel alternatives. For this reconnaissance report, it was decided not to use the current O&M practices as the base conditions, but to use the more effecient dredging and disposal practices planned for the 42-ft and 45-ft channels alternatives.

40-Ft Channel Maintenance.

O&M Dredging Forecast. For each bar between RM's 3 and 107, an estimate has been made of future O&M dredging for the 40-ft channel. The 50-yr O&M dredging forecast for the Columbia and Lower Willamette rivers is shown on Figure 6. A decline in dredging is expected to occur as sediment supplies for some of the large cutline shoals are gradually depleted by dredging and upland disposal. This process will be most significant near old shoreline disposal sites. The 50-year O&M dredging forecast totals approximately 225 mcy.

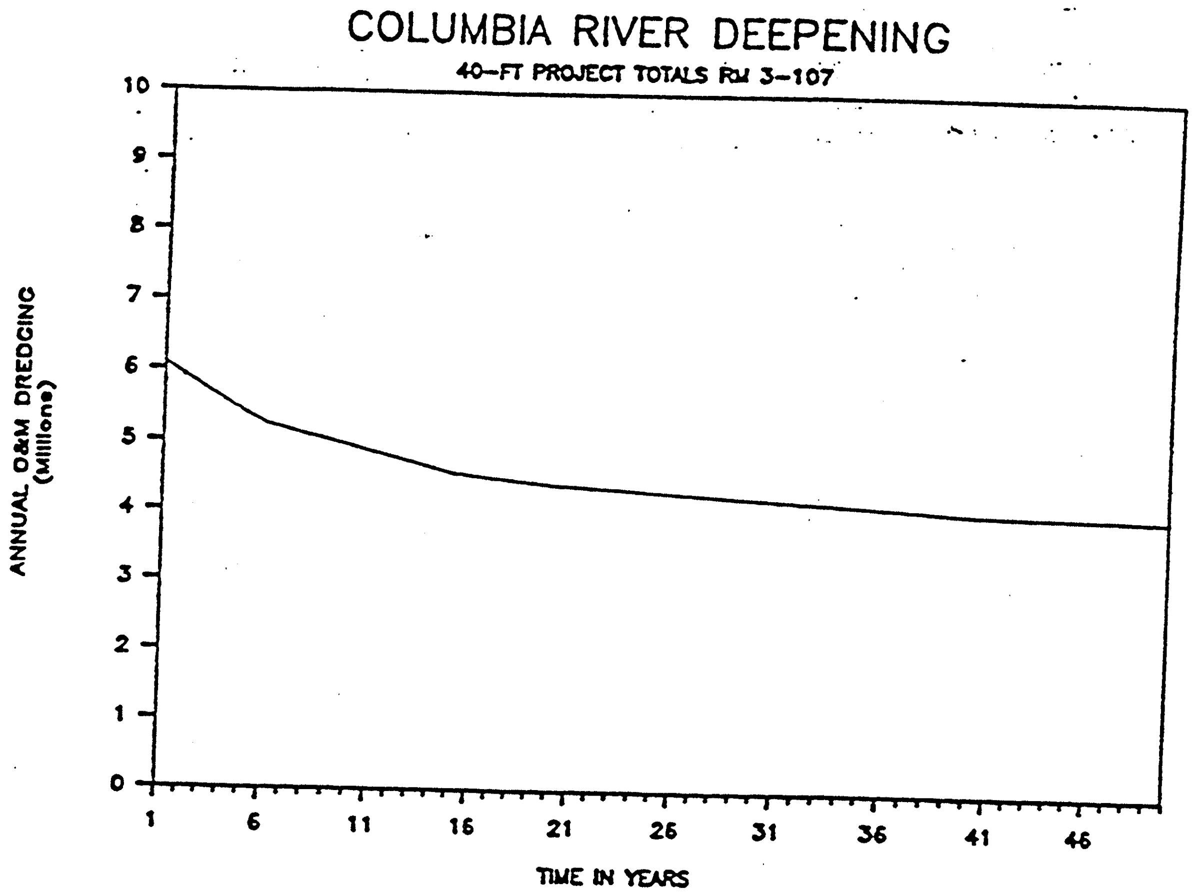

Figure 6. 40-Ft Channel 50-Yr O&M Forecast.

Dredging and Disposal Practices. O&M dredging operations for the 40-ft channel Base Condition are changed from the current practices. Clamshells may join the hopper and pipeline dredges in O&M work, especially in the estuary. Pipeline dredges will still do most of the dredging upstream of RM 20, but disposal will be upland, away from the easily eroded shoreline. More detailed explanations of disposal locations and use are given elsewhere in this report.

Ocean disposal of material from the estuary may make it viable to use clamshells, as well as hopper dredges in the estuary. There will still be a large in-water disposal site in the vicinity of RM 6. This will allow hopper dredges working at the mouth, to continue to work on estuary bars when they can not work at the mouth because of adverse conditions. In the upper estuary, hopper and clamshell dredges will continue to dispose in sumps, where material will be latter rehandled to upland sites. As the navigation channel gets deeper, the availability of good flowlane disposal sites becomes more restricted. However, there are still suitable flowlane sites downstream of Puget Island to allow hopper or clamshell dredges to work the small shoals.

Pipeline dredges will continue to be used in the upper estuary, both to remove shoals and to empty the sumps used by the hopper or clamshell dredges. Disposal sites must be expanded to handle the material expected over the next 50 years. Pipeline dredges will also dredge the large shoals upstream of RM 25. Disposal will be to new upland sites located near the shoals.

Pipeline dredges are planned to do most of the dredging between RM's 20 and 90. For this reconnaissance phase, the important change for the pipeline dredges will be in how they dispose of material. The practice of disposing at unstable shoreline sites will be discontinued and almost all disposal will be in upland sites. Disposal practices will be examined further during the feasibility phase of the project, to determine the most advantageous practices.

Upstream of RM 90, upland disposal sites are hard to locate. In this reach hopper or clamshell dredges will be used so O&M material can be placed in either a small sump near RM 93 and a large sump near RM 103.

AMD was held at 5 ft below authorized depth, including rock areas. Only 2 ft of AMD was used in the Willamette River reach.

WITH PROJECT CONDITIONS

42-FT Channel Alternative.

O&M Dredging Forecast. The 42-ft channel would extend from RM 3 to RM 48 in the Columbia River. This channel would be 600 ft wide and follow the same alignment as the existing 40-ft channel. Upstream of RM 48 the channel would be unchanged from the existing 40-ft channel. Due to the limitations of the current disposal practices discussed earlier, disposal practices will be revised for the new 42-ft channel. More ocean and upland disposal will be done and shoreline (beach nourishment) disposal will generally be stopped.

Over the project life, the 42-ft channel will require 27 mcy more O&M dredging than the 40-ft channel, for a 50-year total of 252 mcy. The majority of the O&M dredging increase will be due to new or larger cutline shoals. The additional 2 ft of depth will increase the amount of material that must erode from side-slopes adjacent to the cutline shoals for the river to reach equilibrium. As shown in Figure 7, the additional material will keep the annual O&M dredging for the 42-ft channel higher than that of the 40-ft channel throughout the project life.

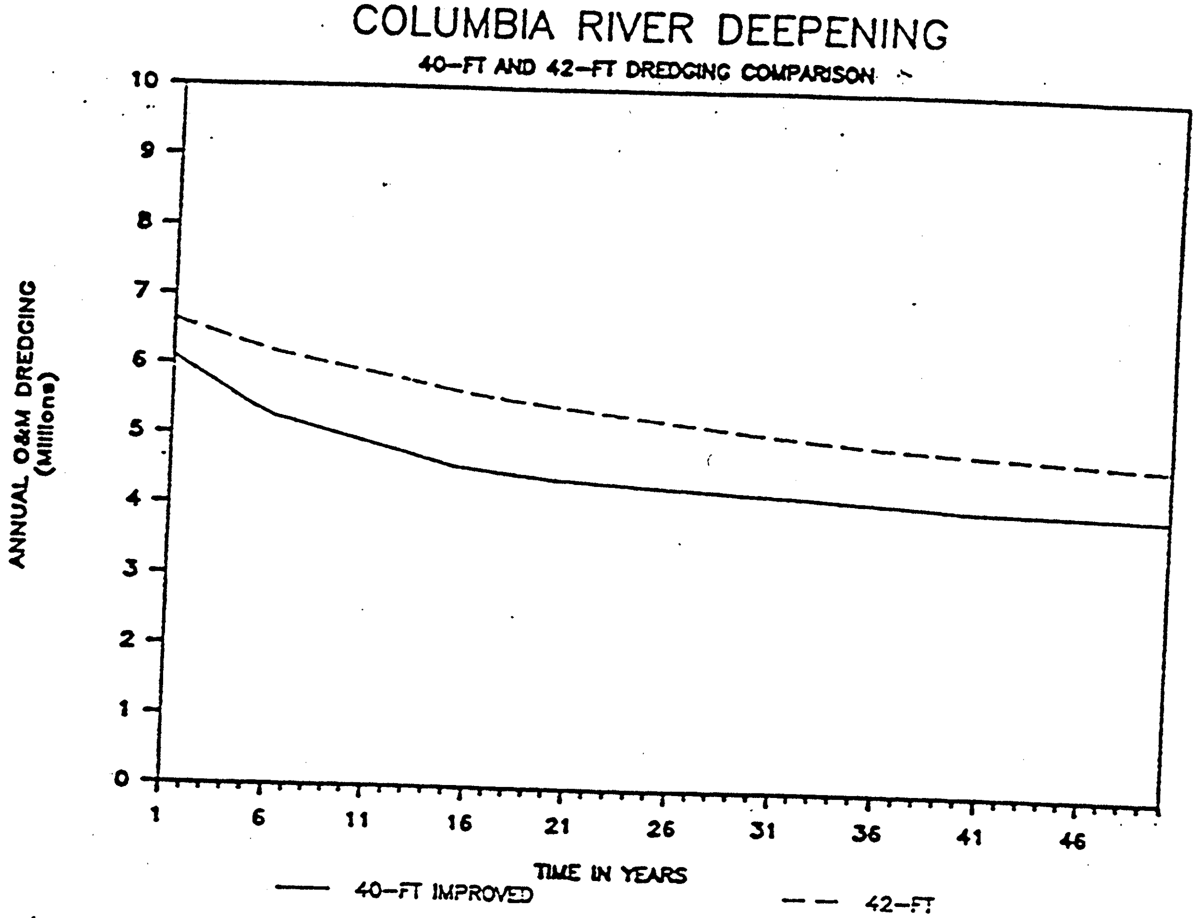

Figure 7. 42-Ft Channel 50-Yr O&M Forecast.

Dredging and Disposal Practices. O&M dredging operations for the 42-ft channel will be the same as those assumed for the Base Condition 40-ft channel maintenance. Clamshells may join the hopper and pipeline dredges in O&M work, especially in the estuary. Pipeline dredges will still do most of the dredging between RM's 20 and 90, but disposal will be upland, away from the easily eroded shoreline. Upstream of RM 90, dredging will be by clamshell and hopper dredges, with disposal at an in-water sump.

AMD will remain at 5 ft below authorized depth, except in rock areas, where only 2 ft is planned. This change will not impact O&M dredging, but may cause problems for very deep draft ships.

No new river control structures are planned for the 42-ft channel.

45-FT Channel Alternative.

The 45-ft channel would extend from RM 3 to RM 107 in the Columbia River and from RM 0 to RM 11 in the Willamette River. Channel alignment and the 600-ft width remain unchanged from the existing 40-ft channel. This channel also will use 5-ft AMD, except for only 2-ft AMD in rock areas and the Willamette River. Because of the greater depth and additional length, the 45-ft channel will increase O&M dredging much more than the 42-ft channel. The channel bottom is very near the riverbed for most of its length. Given the active nature of the Columbia River's bed, this raises the potential for shoaling problems in the navigation channel.

50-Yr O&M Dredging Forecast. A 50-yr O&M dredging forecast was made for the 45-ft channel following the same method as used for the 40- and 42-ft channels. Each bar was examined to determine what type of shoaling can be expected and how much material is available to supply the shoal. It was found that the 45-ft depth would greatly increase the amount of shoals throughout the Columbia River portion of the channel. The O&M dredging is forecast to total 297 mcy over the 50-yr project life. This is 72 mcy more than is forecast for the 40-ft channel Base Condition. Again as with the 40-ft channel, dredging will slowly deplete the available sediment supply as material is transferred from the riverbed to upland disposal sites. The 50-yr dredging forecast is shown in Figure 8. As the sediment supply to the shoals is depleted, there will be a corresponding decline in the annual O&M dredging.

New river control structures were not considered during this phase of study. They could significantly reduce the O&M dredging required to maintain the 45-ft project and should be included in the feasibility phase of this study.

Dredging and Disposal Practices. As with the 40-ft channel Base Condition, the proposed dredging and disposal practices vary along the channel depending on the disposal options available. Hopper, clamshell, and pipeline dredges are all expected to all be used in the 45-ft channel. The lack of stable shoreline disposal sites and suitable flowlane sites lead to a significant increase in upland disposal.

Clamshell dredges are expected to assume some of the dredging currently done by hopper dredges, especially at locations that have long distances to disposal sites. The main work areas for hopper or clamshell dredges will be in the estuary and in the Portland/Vancouver area. In the estuary, ocean disposal is planned for most of the O&M material from downstream of RM 20. An in-water disposal site within the estuary will be maintained for use by hopper dredges that can not work the entrance due to bad weather. An in-water sump near RM 21 can be used by either hopper or clamshell dredges. Material in the sump would be placed in the upland site by a pipeline dredge. Hopper dredge use between RM's 30 and 90 will be very restricted because of the lack of areas deeper than the maximum dredging depth of -50 ft CRD. Hoppers will be able to work only the smaller shoals with very deep water nearby. Upstream of RM 90, upland disposal sites are hard to locate. In this reach hopper or clamshell dredges will be used so O&M material can be placed in either a small sump near RM 93 and a large sump near RM 103. If contaminated material needs to be dredged during project construction, hopper or clamshell dredges could be used to dispose and cap the material in in-water disposal areas.

Pipeline dredges are planned to do most of the dredging between RM's 20 and 90. For this reconnaissance phase, the important change for the pipeline dredges will be in how they dispose of material. The practice of disposing at unstable shoreline sites will be discontinued and almost all disposal will be in upland sites. Disposal practices will be examined further during the feasibility phase of the project.

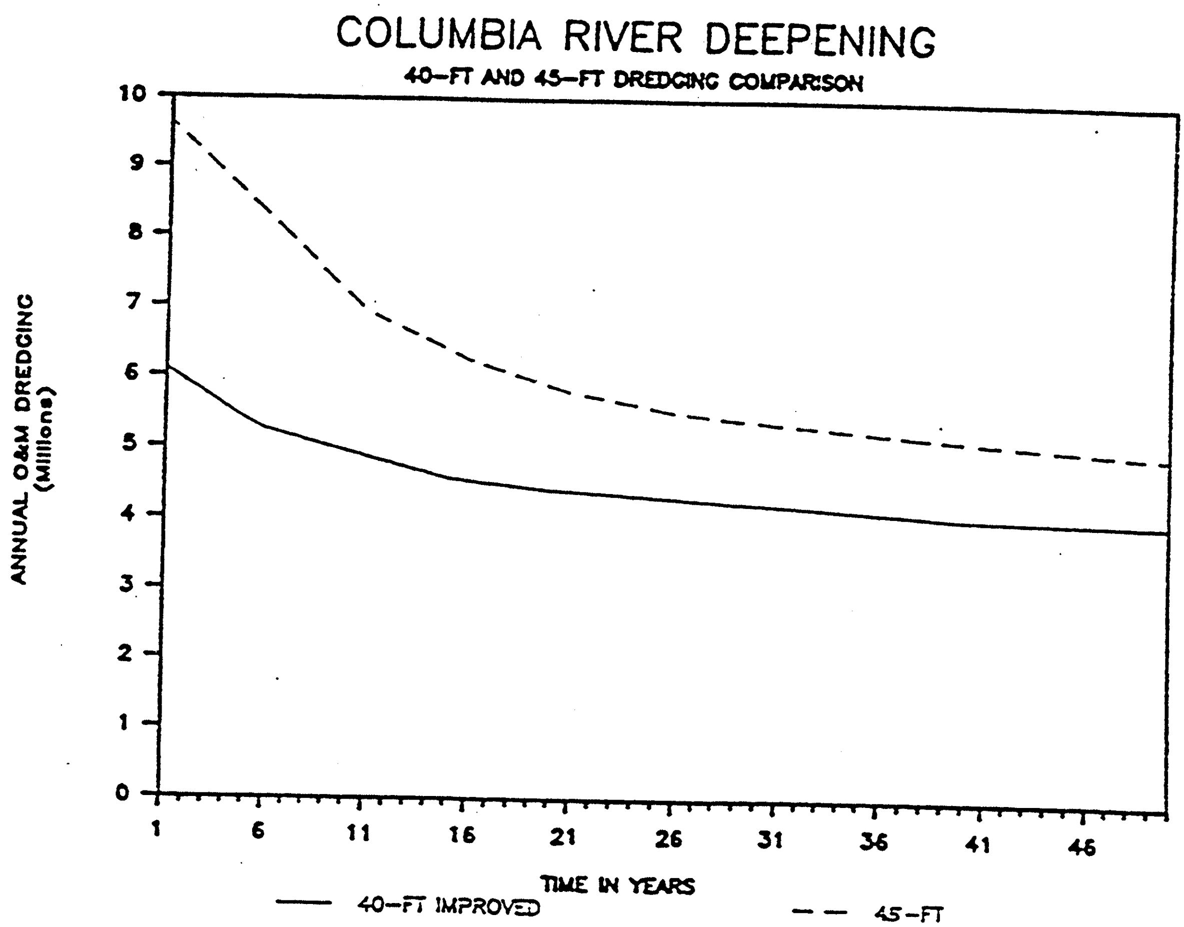

Figure 8. 45-Ft Channel 50-Yr O&M Forecast.

HYDRAULIC AND SEDIMENTATION IMPACTS

The hydraulic and sedimentation impacts of the 42- and 45-ft alternatives will generally be the same type, but will be larger for the deeper and longer 45-ft channel. The potential impacts are discussed only in general terms in the following paragraphs. The specific impacts will depend on the depth, width, and length of the selected navigation channel and location along the rive. While deepening may cause some site specific concerns, the overall impacts will be small compared to those that have occurred during the last 100 years of river development.

Hydraulic Impacts.

The hydraulic impacts of the deepening are expected to be small and will vary depending on location. In the estuary, a deeper channel may result in slightly higher velocities in the main channel. However, the Columbia River Coal Export Channel, Technical Report (USACE, Portland, 1987) suggests that any resulting changes to estuary circulation will be hard to distinguish from normal variations in the existing system. The large disposal sites at Estuarine 1 and 2 will alter local flow patterns, but will be designed to minimize effects on the larger circulation patterns. Upstream of the estuary, the velocity and water surface elevation changes will vary depending on tide, river discharge conditions and location. The channel will not be uniformly deepened, as some reaches are currently deeper than the proposed new depths. In general, one impact might be lower freshet elevations and velocities. Given the wide variation in conditions, it is not possible in this reconnaissance phase to accurately determine the full range of hydraulic impacts. However, the changes are again likely to be so small that they can not be distinguished from existing variations. If specific questions, concerns, or conditions can be identified, then a detailed hydraulic analysis could be performed during the feasibility study.

Sedimentation.

The bed of the Columbia River is not now stable. Bedload movement is the major cause of shoaling in the 40-ft channel. Deepening the navigation channel will increase the instability of the riverbed and result in more shoaling. The deeper cuts will increase the transverse slope of the bed toward the cutline, deflecting more bedload toward the large cutline shoals. As O&M dredging removes sediment from the shoals, more sediment will move from the side-slopes into the shoal areas. Through this process, areas adjacent to the shoals will become deeper, until an equilibrium transverse slope is reached. The effects of this bed erosion are likely to extend all the way to shore and eventually lead to increased shoreline erosion. The shoreline erosion will mainly occur along the sandy beaches created by past dredged material disposal. The erosion of shallow areas in the estuary that is currently occurring, will probably continue for a longer time with a deeper channel. Erosion of the natural silt/clay banks along the Columbia River is not expected to increase significantly. In the Willamette River, the extensive development reduces the potential for shoreline erosion.

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APPENDIX D

PROJECT SEDIMENT QUALITY EVALUATIONS

Sediment Evaluations Willamette River

1986 August/September, Lower Willamette. Seven samples were collected and analyzed for physical and volatile organic solids. Sediments were found to be fine-grained high in organics and therefore would require chemical analyses before unconfined in-water disposal would be allowed.

1988 March /April, Lower Willamette. Samples were collected using a gravity corer, ponar grab sampler, and a vibracorer. Physical, volatile solids, ammonia, TOC, metals, pesticides, PAH's, and elutriate testing was performed on the samples. Elutriate and solid-phase bioassays were conducted on material collected at RM4.4, 5.1, 7.1 and 7.3. Sediments from RM 10.7 and downstream consisted of silt with individual sandy or clayey layers. Sediments from RM 11.3 were very sandy in contrast to other sites. At RM 11.7 it was comprised mostly of coarse gravel.

Some sediments had elevated levels for cadmium, copper, mercury, lead, zinc, DDD, and total PAH's. Lead and total PAH concentrations at the Broadway Bridge RM 11.7 were above concern levels. Elevations also occurred with PCB's at RM 10.3, DDT at RM 7.3, and cadmium at the Oregon Slough. Elutriate from Doane Lake sediments was toxic to D. magna, while the less disturbed sediments in the solid phase test were not. Most sediments are acceptable for unconfined in-water disposal in the Columbia River. Shoals from RM 7.0- 7.5, 10.3, and 11.7 should be placed in an alternate confined in-water or upland disposal site.

1989 September, Lower Willamette Supplemental. Elutriate tests were conducted on two samples from the Oregon Slough collected in 1988. Testing was performed by Battelle Pacific Northwest Division Marine Science Laboratory. The bulk chemical tests showed relatively high cadmium levels in November 1988. However results of the elutriate test showed that the release was less than 0.039 mg/L soluble cadmium. Based on these results the sediments are acceptable for unconfined in-water disposal.

1989 July, Burlington Northern Railroad Bridge. Three samples were collected with a vibracore. Each core was split in half logged and subsampled for physical and chemical analysis. Physical analysis revealed that sediment was mostly fines. Chemical analysis reveled that metals, TOC, and oil and grease concentrations were low and typical of uncontaminated river sediment. Pesticides, PCB's, PAH's, phthalates, and phenols were below the method detection limit. Sediment was determined to be acceptable for unconfined in-water disposal.

1992 June, Portland Harbor. The purpose of this study was to evaluate the shoal material in the Lower Willamette River. There were five sample locations. Physical, TOC, volatile organic solids, metals, pesticides, PCB's, PAH's, phenols, and sulfide analysis was performed on some samples. Chemical analysis reveled zinc concentration exceeded the EPA concern level. Very low levels of DDE and DDD were detected in some of the samples. Endosulfan II and methoxchlor was detected in particular samples. PAH's were detected in low concentrations in five of the six samples. One sample exceeded the established concern levels. Phenols were detected in three samples but below concern levels.

From RM 8.0 to 10.2 sediment was determined to be acceptable for unconfined in-water and upland disposal. The sediment sample from RM 10.3 had the most contaminates of all samples. It was anticipated that the this shoal would not be dredged at this time until further evaluations are conducted.

Sediment Evaluations Columbia River

1952-1957, Sediment samples were collected yearly before and after dredging from dredge bins and subjected to physical analysis between July 1952 and September 1957 (form Table 3, DMRP Tech Rpt. D-77-30, Appx. A).

1980-1987, As a result of the eruption of Mt. St. Helens in 1980 and subsequent deposition of large quantities of material in the Columbia River yearly sediment samples were collected between RM 4 and RM 90. Sediment gradations were conducted on suspended and bedload material. A document presenting the results was published in December 1988 by the Sedimentation Section, Hydraulics and Hydrology Branch, Engineering Division, Portland District, USACE.

1982 August, Sediment samples were collected from the main navigation channel from Mouth of the Columbia River to Cathlamet Bay at RM 18.2 and subjected to elutriate and bulk chemical as well as physical analysis. This work was performed by the USGS under contract with the USACE, Portland District. Data is provided in USGS Open File Report 84-133.

1983 July, One sediment sample was collected from the main navigation channel at approximately RM 2.8 and subjected to elutriate and bulk chemical as well as physical analysis. Cadmium was found to be associated with the 1 percent material finer than 100 microns (very fine sand) at a concentration of 2.2 ppm. As the concentration of organic carbon and iron (both of which would hinder biological uptake) was small: it was speculated that the cadmium may be in a form available to benthic organisms. However, bulk concentrations of cadmium in undifferentiated dredged material would be 0.022 ppm (2.2 ppm/100) well below established concern levels. This work was performed by the USGS under contract with the USACE, Portland District. Data is provided in USGS Open File Report 86-4088.

1986 September, Three 30-foot vibracores were collected from the main navigation channel as part of the October 1987 Columbia River Coal Export Channel technical study. The cores were subdivided by depth and various subsamples were subjected to bulk and elutriate chemical as well as physical analyses.

1990 May, Sediment samples for chemical (dioxin/furan and TOC) and physical (grain size and volatile solid) analyses were collected within the proposed channel alignment at various locations along the lower Willamette River (WR) and Columbia River (CR) between Nay 3, 1990 and Nay 18, 1990. Sediment samples were collected from 5 general reaches of the two rivers using a Benthos gravity corer . These reaches included Portland Harbor Area (RN 4+10 to RN 11+00) on the Willamette River and Camas (RN 118+26), St. Helens (RN 85+45), Longview (RN 63+00 to RN 65+40) and Wauna (RN 38+00 to RN 43+05) on the Columbia River.

A total of nineteen (19) samples or composites were analyzed for the presence of dioxins/furans. Though various isomers of dioxin/furan were detected in all of the samples tested many of the individual isomer concentrations found in the Columbia River samples can be attributed to background levels in the analytical system. In addition concentrations found in samples from the Columbia River are orders of magnitude below those found in the Willamette River samples. The isomer 2,3,7,8-TCDD was confirmed in two (2) of the twenty (20) analyses; WRGC-4 at 0.63 pptr and WR-GC-7Rep at 0.62 pptr. The associated furan isomer, 2,3,7,8-TCDF, was detected at concentrations ranging from a low of 0.73 pptr (WR-GC-7) to a high of 110.0 pptr (WR-GC4) in the Willamette River samples. WR-GC-4 was collected from the Doan Lake area where contamination of DDD, DDT and PAHs have been noted in the past.

It was concluded that in the Columbia River, significant dioxin/furan contamination of the sediments within the Columbia River Channel Deepening project is not evident. In the Willamette River, though 2,3,7,8-TCDD and the lower weighted dioxins were found only at low levels, the higher weighted less toxic dioxins and the furans are significantly elevated above background. Further testing and evaluation will be required in this area.

APPENDIX E

PARAMETERS AND METHODS

QA2 DATA REQUIREMENTS

CHEMICAL VARIABLES

ORGANIC COMPOUNDS

The following documentation is needed for organic compounds:

A cover letter referencing or describing the procedure used and discussing any analytical problems

Reconstructed ion chromatograms for GC/MS analyses for each sample

Mass spectra of detected target compounds (GC/MS) for each sample and associated library spectra

GC/ECD and/or GC/flame ionization detection chromatograms for each sample

Raw data quantification reports for each sample

A calibration data summary reporting calibration range used [and decafluorotriphenylphosphine (DFTPP) and bromofluorobenzene (BFB) spectra and quantification report for GC/MS analyses]

Final dilution volumes, sample size, wet-to-dry ratios, and instrument detection limit

Analyte concentrations with reporting units identified (to two significant figures unless otherwise justified)

Quantification of all analytes in method blanks (ng/sample)

Method blanks associated with each sample

Recovery assessments and a replicate sample summary (laboratories should report all surrogate spike recovery data for each sample; a statement of the range of recoveries should be included in reports using these data)

Data qualification codes and their definitions.

METALS

For metals, the data report package for analyses of each sample should include the following:

Tabulated results in units as specified for each matrix in the analytical protocols, validated and signed in original by the laboratory manager

Any data qualifications and explanation for any variance from the analytical protocols

Results for all of the QA/QC checks initiated by the laboratory

Tabulation of instrument and method detection limits.

All contract laboratories are required to submit metals results that are supported by sufficient backup data and quality assurance results to enable independent QA reviewers to conclusively determine the quality of the data. The laboratories should be able to supply legible photocopies of original data sheets with sufficient information to unequivocally identify:

Calibration results

Calibration and preparation blanks

Samples and dilutions

Duplicates and spikes

Any anomalies in instrument performance or unusual instrumental adjustments.

Parameter	Prep Method	Analysis Method	PSDDA SL	PSDDA BT	PSDDA ML	SMS SQS	July 96 draft SMS detection limits (1)	1988 LAET
Chlordane	3540	8081	10	37	---	---	---	---
Dieldrin	3540	8081	10	37	---	---	---	---
Heptachlor	3540	8081	10	37	---	---	---	---
Lindane	3540	8081	10	---	---	---	---	---
Total PCBs	3540	8081	130	38 (13)	2500	12	6	130

1. Recommended Sample Preparation Methods, Cleanup Methods, Analytical Methods and Detection Limits for Sediment Management Standards, Chapter 173-204 WAC, Draft - July 1996.

2. Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound, Puget Sound Estuary Program, March, 1986.

3. Recommended Methods for Measuring TOC in Sediments, Kathryn Bragdon-Cook, Clarification Paper, Puget Sound Dredged Disposal Analysis Annual Review, May, 1993.

4. units: ug = microgram, mg = milligram, kg = kilogram, dw = dry weight, oc = organic carbon.

5. Test Methods for Evaluating Solid Waste. Laboratory manual physical/chemical methods. Method 3050, SW-846, 3rd ed., Vol 1A, Chapter 3, Sec 3.2, Rev 1. Office of Solid Waste and Emergency Response, Washington, DC.

6. Graphite Furnace Atomic Absorption (GFAA) Spectrometry - SW-846, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986.

7. Inductively Coupled Plasma (ICP) Emission Spectrometry - SW-846, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986.

8. Test Methods for Evaluating Solid Waste. Laboratory manual physical/chemical methods. Method 7471, SW-846, 3rd ed., Vol 1A, Chapter 3, Sec 3.3. Office of Solid Waste and Emergency Response, Washington, DC.

9. Sonication Extraction of Sample Solids - Method 3550 (Modified), SW-846, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986. Method is modified to add matrix spikes before the dehydration step rather than after the dehydration step.

10. GCMS Capillary Column - Method 8270, SW-846, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986.

11. Purge and Trap Extraction and GCMS Analysis - Method 8260, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986.

12. Soxhlet Extraction and Method 8081, Test Methods for Evaluating Solid Waste Physical/Chemical Methods, EPA 1986.

13. Total PCBs BT value in mg/kg oc.

Parameter	Prep Method	Analysis Method	PSDDA SL	PSDDA BT	PSDDA ML	SMS SQS	July 96 draft SMS detection limits (1)	1988 LAET
CONVENTIONALS:								
Total Solids (%)	---	Pg.17 (2)	---	---	---	---	---	---
Total Volatile Solids(%)	---	Pg.20 (2)	---	---	---	---	---	---
Total Ofganic Carbon (%)	---	DOE (3)	---	---	---	---	---	---
Grain Size	---	Modified ASTM with Hydrometer	---	---	---	---	---	---
METALS			units: mg/kg dw (4)			units: mg/kg dw	units: mg/kg dw	
Arsenic	3050 (5)	GFAA (6)	57	507.1	700	57	19	57
Cadmium	3050	GFAA	0.96	---	9.6	5.1	1.7	5.1
Chromium	3050	GFAA	---	---	---	260	87	260
Copper	3050	ICP (7)	81	---	810	390	130	390
Lead	3050	ICP	66	---	660	450	150	450
Mercury	7471 (8)	7471	0.21	1.5	2.1	0.41	0.14	0.59
Nickel	3050	ICP	140	1022	---	---	---	>140
Silver	3050	GFAA	1.2	4.6	6.1	6.1	2.0	>0.56
Zinc	3050	ICP	160	---	1600	410	137	410
ORGANICS								
LPAH			units: ug/kg dw			units: mg/kg oc	units: ug/kg dw	
Naphthalene	3550 (9)	8270 (10)	210	---	2100	99	700	2100

Parameter	Prep Method	Analysis Method	PSDDA SL	PSDDA BT	PSDDA ML	SMS SQS	July 96 draft SMS detection limits (1)	1988 LAET
Acenaphthylene	3550	8270	64	---	640	66	433	>560
Acenaphthene	3550	8270	63	---	630	16	167	500
Fluorene	3550	8270	64	---	640	23	180	540
Phenanthrene	3550	8270	320	---	3200	100	500	1500
Anthracene	3550	8270	130	---	1300	220	320	960
2-Methylnaphthalene	3550	8270	67	---	670	38	223	670
Total LPAH			610	---	6100	370	---	5200
HPAH			units: ug/kg dw			units: mg/kg oc	units: ug/kg dw	
Fluoranthene	3550	8270	630	4600	6300	160	567	1700
Pyrene	3550	8270	430	---	7300	1000	867	2600
Benzo(a)anthracene	3550	8270	450	---	4500	110	433	1300
Chrysene	3550	8270	670	---	6700	110	467	1400
Benzofluoranthenes	3550	8270	800	---	8000	230	1067	3200
Benzo(a)pyrene	3550	8270	680	4964	6800	99	533	1600
Indeno(1,2,3-c,d)pyrene	3550	8270	69	---	5200	34	200	600
Dibenzo(a,h)anthracene	3550	8270	120	---	1200	12	77	230
Benzo(g,h,i)perylene	3550	8270	540	---	5400	31	223	670
Total HPAH			1800	---	51000	960		12000
PESTICIDES & PCBs			units: ug/kg dw			units: mg/kg oc	units: ug/kg dw	
Total DDT	---	---	6.9	50	69	---	---	---
p,p'-DDE	3540 (12)	8081 (12)	---	---	---	---	---	9
p,p'-DDD	3540	8081	---	---	---	---	---	16
p,p'-DDT	3540	8081	---	---	---	---	---	>6
Aldrin	3540	8081	10	37	---	---	---	---